Volume 31 No. 1 January–March 1981

impact of science on society

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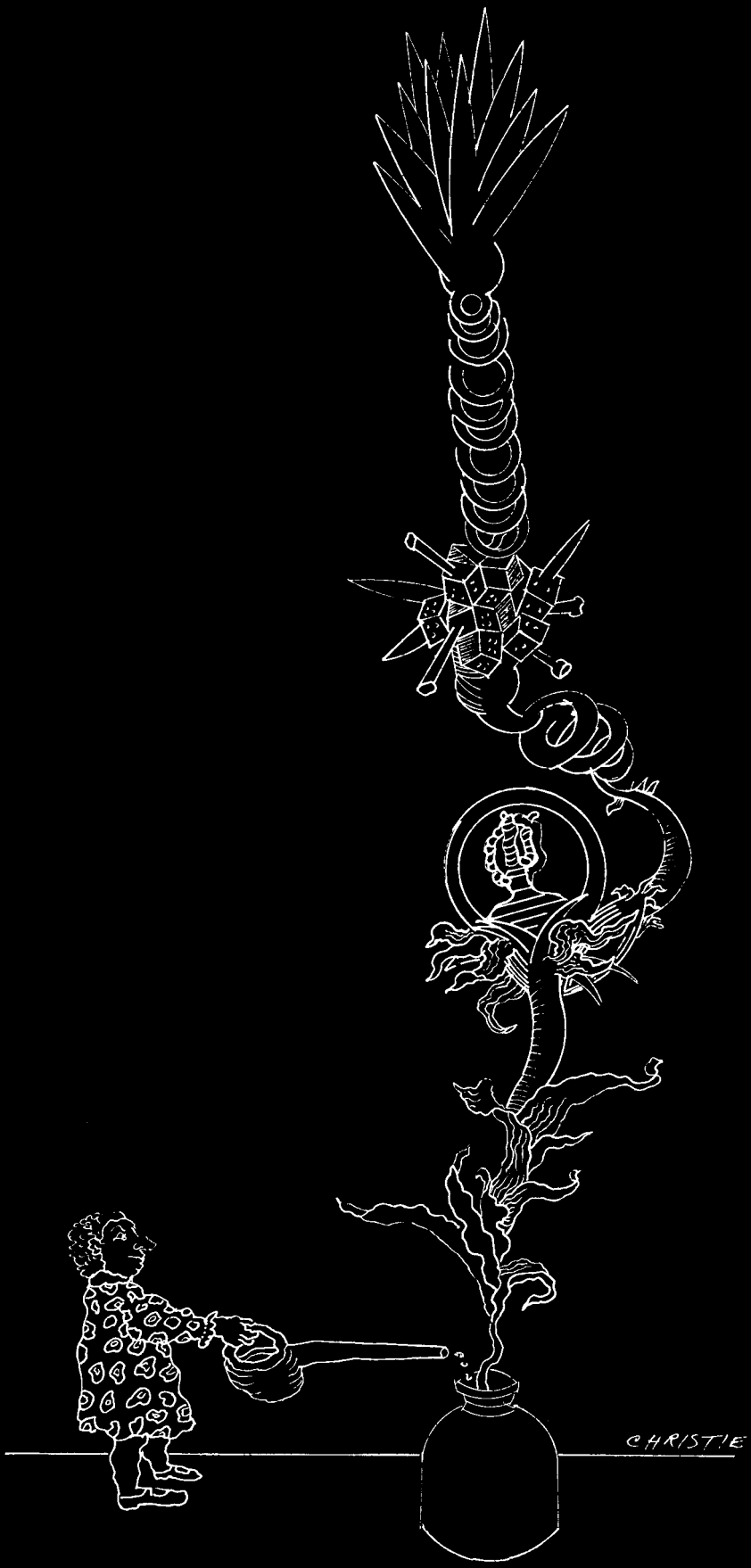
impact

Weapons from science

Civilization's pitfall


CHRISTIE

Technical sophistication and the tranquil state

The artist whose work appears throughout this issue is Dorothy Christie, who states: 'I was born in a small Canadian town and studied fine arts at the Ontario College of Art, a school which at the time was devoted to the figurative tradition. Later, I studied lithography in London and etching in Paris.' Ms Christie has exhibited her etchings in various salons in Paris (Les Réalités Nouvelles, Le Trait, among them); she is currently concentrating on painting.

Our artist comments: 'When I was asked to illustrate this issue on the development of modern weapons, I accepted because I was largely unacquainted with the subject—a topic one does not like to think about every day. Reading on the subject turned out to be a depressing experience. As I did so, echoes from the famous Elizabethan playwright came to mind—such as, "Life is but a destructive game" and "All of life is a chess-board over which amble the remnants of civilization".

'I found a certain solace, however, in the invention of the neutron bomb. In the event of the use of this weapon, perhaps museums containing the works of Rembrandt, Vermeer and the Zen masters, Persian miniatures, Russian icons and Chinese porcelains might still be left standing. I was struck by the immensely sophisticated yet destructive potential of our brain and—at the same time—its consistent disregard for the horrific consequences of nuclear war; and I was impressed by the close resemblance between our inventions and natural forms.

'The idea came to me that perhaps mankind should stake out territory on another planet where some could practise war games and leave the rest of us, more peaceable human creatures, to live out our days here in tranquillity.'

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Civilization's pitfall

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An invitation to readers
Reasoned letters which comment, pro or con, on any of the articles printed in *impact* or which present the writer's view on any subject discussed in *impact* are welcomed. They should be addressed to the Editor, *impact of science on society*, Unesco, 7 place de Fontenoy, 75700 Paris (France). Requests to reproduce articles published in *impact* should be addressed to the Editor.

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Reminder to readers

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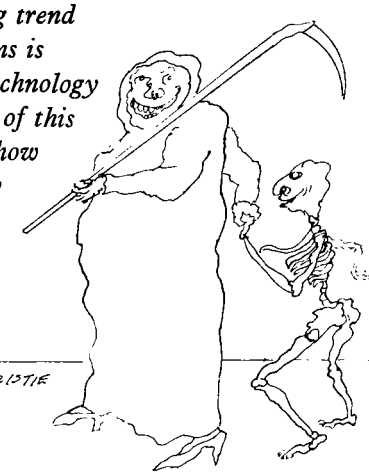
The Economic and Social Council of the United Nations has recommended that measures be taken by the United Nations Specialized Agencies to publicize and condemn the growing trend among Member States to arm for war. The United Nations is especially concerned about the calls made on science and technology to aid and abet the process of armament. The present issue of this journal is offered so that its readers can better understand how scientific research and technical innovation are increasingly diverted to reinforce the ability of some nations to wage warfare with more means than are needed for self-defence.



Comment

'Man has the right to disarmament, especially to "dis-superarmament"', reminds Edgar Faure.[1] The Universal Declaration of Human Rights (32 years old and still observed more in theory than in practice) is the solemn promulgation of certain basic rights of man: equality before the law, protection from arbitrary interference with privacy, freedom of thought and expression, freedom of movement within a state or to escape persecution—these are a few of the provisions set forth during the United Nations General Assembly in 1948. While individual rights are a major preoccupation of the authors whose articles follow, the problem of military research affects other rights less frequently mentioned: the right to a standard of living adequate for well-being (food, housing, medical care), and the rights to education and employment and leisure.

In all these areas, continuing massive investment in military research and development (R&D) constrains the capacity of scientific research and innovative technology to serve man's essential rights—not to mention the right to harmony and peace, what Article 28 of the Universal Declaration calls the right to 'a social and international order in which the . . . freedoms set forth in this Declaration can be fully realized'.

It is a substantial event for the United Nations Educational, Scientific and Cultural Organization to release a publication in which criticism appears of Member States, who are both board members and principal beneficiaries of the Organization's work. Yet it is some of the Member States themselves who are arming (several at an exponential rate), and it is they who must be persuaded to scale down their armaments or even to disarm. Indeed, this is a vital step forward in the advancement of a new information and communication order for the world as a whole. The World Congress on Disarmament Education, held

last June in Paris at Unesco Headquarters, adopted ten guiding principles on disarmament education. One of these is the promotion of disarmament, 'to make people aware of the need for a higher degree of co-operation at all levels'.[2] The contents of the journal you are holding is one of the instruments of such awareness.

The current arms race is not, as some of our authors emphasize, a concourse reserved to the superpowers only. Even small, developing countries (some of them extremely poor) have chosen the same path, overspending in the acquisition of military material and replacement parts at the cost of elementary social needs. Regardless of where a nation is situated along the big power–little power spectrum, the economic disruption caused by the race to arm is heedless folly and can be reversed.

The articles in this issue will lead the reader to wonder about the key problem of how really to control the future development of military R&D. Besides some of the ideas expressed by authors Röling, Sundaram and others, the reader can consult the extensive literature being produced by distinguished institutions already grappling with the problem: peace research groups in Brussels, Bucarest, London, Mexico City, Ottawa, Tokyo—to name only a few—as well as the organizations mentioned throughout this issue.[3] A particularly condensed treatment of the issue of control has been published by Owen Wilkes of New Zealand in the *Bulletin of Peace Proposals*.[4]

Readers' reactions to the problem of military R&D are earnestly solicited, especially as to additional concrete measures towards disarmament which our authors may have overlooked. ■

impact *of science on society*

Notes

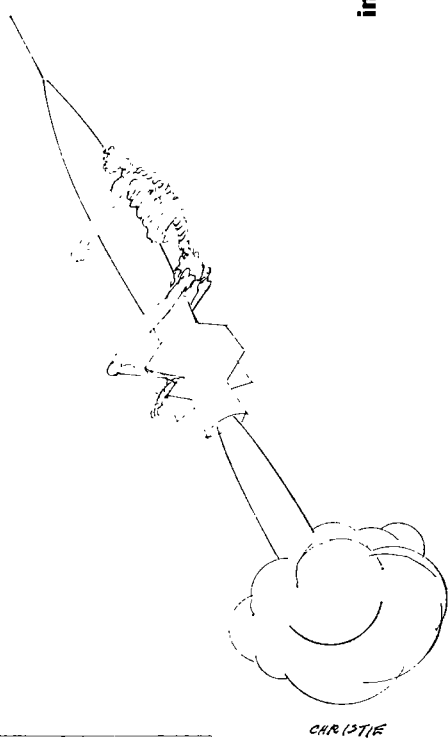
1. Speaking at the Peace Forum held at Unesco, Paris, 12–16 November 1979. Edgar Faure, a former French prime minister, is a member of the Académie Française.
2. The proceedings and final report of this congress appear in *Bull. Peace Proposals*, Vol. 11, No. 3, September 1980. *The Unesco Courier* of September 1980 is devoted to disarmament education and the results of the congress.
3. For a complete catalogue of the organizations engaged in peace research, see *Peace Research: Trend Report and World Directory*, Paris, Unesco, 1979 (Reports and Papers in the Social Sciences, 43). A revised version will appear this year.
4. O. Wilkes, 'Military Research and Development Programs: Problems of Control', *Bull. Peace Proposals*, Vol. 9, No. 1, 1978. For a detailed account of how military R&D impelled by wartime fervour can know virtually no limits, see R. Jones, *Most Secret War (1939–1945)*, London, Hamish Hamilton, 1978 (hardback); Coronet, 1979 (paperback).

A military journalist examines some of the root-causes of armed conflict as a means to settle disputes—motives whose persistence in the future can be extrapolated. These compel governments to maintain forces for war and the research resources to equip these. There are steps possible, however, in the direction of harmony and peace, to halt military research or at least attenuate its impact on global society.

impact *of science on society*, Vol. 31, No. 1, 1981

Is military R&D a necessary evil?

G. S. Sundaram



Born in India in 1947, Gowri S. Sundaram holds the master of science degree from the University of Manchester Institute of Science and Technology (where he presented his thesis on 'Microwave Power Concentrations—a Biological Hazard'). He worked for several years in the fields of high energy physics and nuclear medicine with High Energy & Nuclear Equipment S.A. in Geneva. In 1974 he joined the staff of International Defense Review, *of which he is now senior editor specializing in military electronics. The author's address is in care of Interavia S.A., Avenue Louis-Casaï 86, 1216 Cointrin/Genève, Switzerland*

Hope and human nature

The great majority of mankind still cherishes the hope, however faint it may seem today, of one day seeing a world wherein all men are considered equal and live together in peace and harmony. We should, by all means, encourage such hopes and make every effort to achieve this Utopian goal. But at the same time, we should be careful not to lose touch with reality.

Dreaming of a peaceful and prosperous world is well and good. Actually achieving it is quite another matter. To begin with, all the nations on earth must participate and do so sincerely. For true universal peace, the nations must decide unanimously to lay down their arms and abide by the rules. Unanimity and good faith are essential, since by disarming, countries lay themselves open to attack and domination by any one country which has not obeyed the rules. It is useless for all the sheep to decide that vegetarianism should prevail throughout the world if the wolf does not also endorse the idea.

Human nature being what it is, a relationship based on peaceful coexistence is not easy to achieve and even less so to maintain over prolonged periods. Mutual fear and distrust, a will to dominate, or a need to safeguard one's own interests are some of the reasons that such a relationship can slowly but steadily deteriorate or even break down abruptly.

If one is a realist and looks around the world today, it will be obvious that the conditions necessary for a true and lasting peace are not widely prevalent. The Utopian dream is still quite far away. The world's affairs are dominated by the two so-called superpowers, the Union of Soviet Socialist Republics and the United States of America. Both have their respective ideologies, allies and geographic regions of influence. The Soviet Union and its allies in Eastern Europe belong to a military alliance referred to as the Warsaw Pact. The United States has a similar treaty with Canada and the industrialized nations of Western Europe, and they form the North Atlantic Treaty Organization (NATO). Caught between these two power blocs are the non-aligned nations, the majority of these coming from the so-called Third World.

At present, an uneasy peace prevails around the world, broken from time to time by regional outbursts of hostilities. There are many areas of potential conflict, where a perpetual state of tension and confrontation exists between neighbouring countries. The main causes for this somewhat precarious situation are: (a) political or ideological differences (as in Central Europe, Indochina or between the USSR and China); (b) religious or ethnic differences (as in Northern Ireland, the Middle East, Malaysia, or between India and Pakistan); (c) tribal differences (as in many parts of Africa); or (d) conflicting claims over disputed territory.

Such delicate relationships are bound to bring about an arms race psychology, with each side acquiring new weapons because of a suspicion that the other has already done so. This can become an endless, frightening and futile process with each side wasting funds which are perhaps badly needed to meet other more pressing demands of society.

The alarming nature of this unnecessary arms buildup was recognized decades ago. Endless conferences have since been convened to discuss arms limitations, disarmament, and mutual force reductions. The progress made does not appear to be significant, since these conferences are still going on while the arms buildup continues.

What the world spends on defence

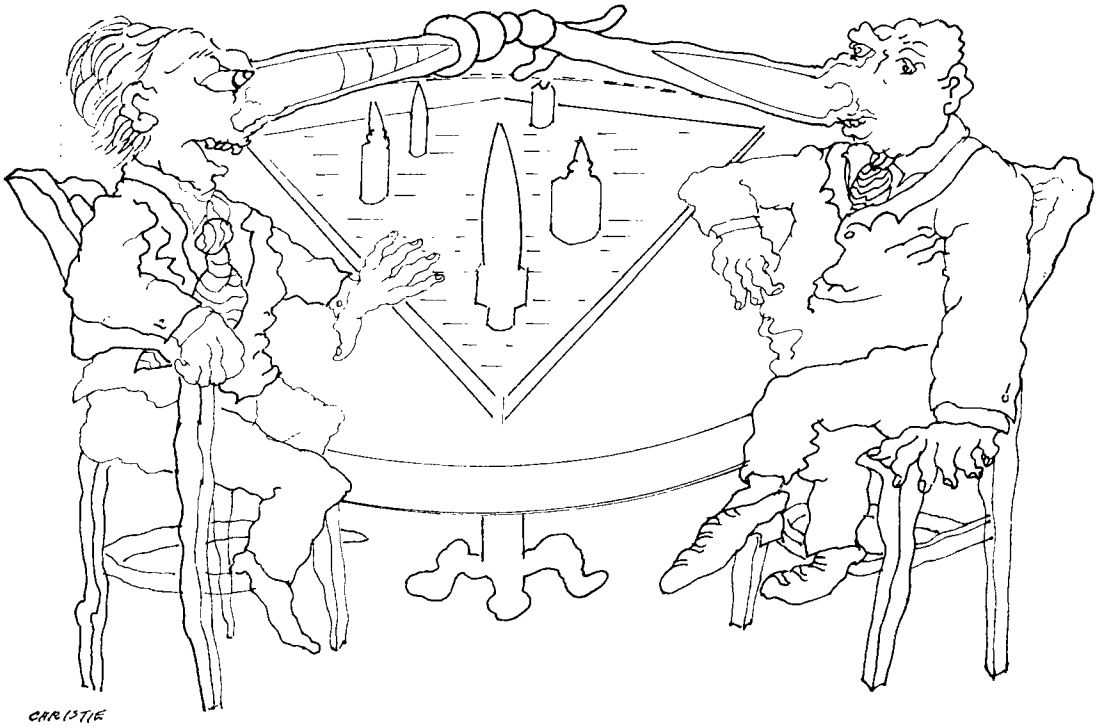
It is, unfortunately, not possible to establish the exact sum spent by all the countries in acquiring weapons and in developing new ones. Each country has its own method of preparing and dividing up its annual budget. Not all countries release even the correct overall value of their military budgets, let alone give full details of their content. In some cases, the figures released for the military budget may not include the cost of acquisition or development of certain equipment because this happens to come under the responsibility of a non-military ministry. Thus much of the information published in the open literature on world defence spending is the result of extrapolations and estimations using justifiable assumptions or, in some cases, just plain guesswork. Another element of confusion is that the cost of living and the type of economy which exists in each country are so varied. Thus a given sum allocated for defence will buy different amounts in each country.

For the purposes of this article, it is sufficient to have an idea of magnitude of the amounts involved rather than exact values. The total United States defence outlay for the 1980 fiscal year was estimated to be $127,400 million; for the fiscal year 1981, the estimate is $142,700 million—representing an increase in real terms (after accounting for inflation of 3.3 per cent over the previous year. With this latest outlay, defence represents 23.2 per cent of the United States federal budget and 5.2 per cent of the gross national product (GNP). Future spending on defence is expected to rise by similar percentages each year during the next five years.

It can only be assumed that the Soviet Union also spends a similar amount on its defence. These two countries account for well over 60 per cent of world military spending. With the addition of the defence outlays of the other countries, it can be seen that the world spends a minimum of $400,000 million on defence annually. It is interesting to note that the world devotes approximately similar amounts to health and education each year. The sum of $400,000 million is also fifteen times more than what the industrialized nations provide as economic aid to the Third World.

In most countries, about 30–50 per cent of the defence budget is actually devoted to weapons procurement, and some 5–10 per cent to military research and development—the remainder being accounted for by pay of the forces and other administrative costs. In the United States, for example, the 1981 fiscal year's military procurement programme is for about $41,000 million while that for military research and development is some $15,000 million.

Again assuming that the Soviet Union spends a similar amount on military research and development, it can be said that the world devotes some $35,000–40,000 million for this purpose every year. Although these figures are approximate, they conform with the general trend in most countries of devoting some 5–10 per cent of the total defence outlay to research and development. As a comparison, some $15,000 million are allocated each year for cancer research throughout the world.



Changing influences in arms procurement

Until only ten years ago, the two superpowers, the Soviet Union and the United States, together with their Warsaw Pact and NATO partners respectively, used to account for more than 80 per cent of the world's military expenditure. The major political and strategic upheavals of the last decade have suddenly propelled the oil-rich nations into prominence, and the Third World's share of all military spending has steadily increased. While the countries belonging to the two main military blocs—NATO and the Warsaw Pact—still spend the same or slightly higher amounts on defence, their share has now diminished to about 70 per cent of the world's total.

Although the Third World comprises well over a hundred countries, more than 50 per cent of the amount spent on arms by this group is accounted for by half a dozen nations. In fact, about three years ago (prior to the Iranian revolution), Egypt, Iran, Israel and Saudi Arabia were responsible for over 40 per cent of the Third World's total, while some twenty countries spent over 80 per cent of the total.

It would perhaps be wise to examine the reasons behind the continuing upward trend in world military expenditures. While defence spending by the industrialized countries went up only marginally during most of the last decade, the last two years have seen a significant increase. In addition, there has been the sudden upsurge in defence spending by Third World countries, which I have mentioned.

During the 1970s, a reasonable dialogue was established between the East and West power blocs (Warsaw Pact and NATO) in an atmosphere called détente. This resulted in a lessening of tensions in Central Europe and, in the West anyway, less emphasis being placed on the defence segments of national budgets. In retrospect, this stability or even downward trend in defence spending appears to have been one-sided, since today the West

finds its forces greatly outnumbered by those of the Warsaw Pact in Central Europe. This realization, compounded by the present deterioration in détente as a result of developments in Afghanistan, has prompted the West sharply to increase defence spending in an effort to catch up with the Warsaw Pact forces.

Regional tensions, shifting political alliances and rival efforts by the superpowers to expand their regions of influence or reduce those of the other have continued to increase the arms buildup in the Third World. The Arab-Israeli confrontation is as strong as ever, in spite of the peace treaty between Egypt and Israel. In fact, this new relationship has perhaps helped increase the state of tension and distrust in the region, where the other Arab nations feel they now have to counter not only the Israeli but also deal with an Egyptian front. Although the American presence in Indochina is no more and the third Viet-Nam war has finished, hostilities are far from concluded in the region. Many parts of Africa and Latin America are in turmoil, with some countries threatened either from outside or inside.

As one country acquires new weapons, its neighbours begin to feel uncomfortable. If it happens to be an aggressive country arming itself, the buildup is seen as a threatening and dangerous development which calls for a similar buildup of one's own arsenal. Even if a hitherto friendly nation is involved in new arms purchases, this is looked upon as a desire by that country to assert its authority or wield political influence over that region. This again may call for a matching buildup, depending on the relative sizes of the countries involved.

In some cases, rival factions within a country will be the cause of an internal arms race. The head of the army, for instance, may have more power and influence than leaders of the other services, and so may be able to procure more arms. This will result in the other leaders trying to follow suit, mainly in order not to lose political potential within the country—irrespective of the fact that the country's military requirements may be in the process of being externally surpassed.

Real role of military R&D

Each country wants to maintain its sovereignty, become prosperous, and thereby raise the living standards of its people. It must not only be able to feed and educate its population, but must also raise the level of technology and build a strong industrial infrastructure.

Above all, the country must be able to protect its people. In the present turbulent age, a country's independence, security and integrity can be guaranteed only by its ability to counter effectively all threats, both from outside and within its borders. Goverments therefore give high priority to building national defence forces.

But strength and independence do not necessarily go hand in hand. It is thus not wise to increase one's strength at the expense of independence, for example, by buying all one's defence equipment from other countries. This can be dangerous and compromise national security, particularly at a time of crisis. The supplying country could stop shipments of equipment and spares for political motives, or the crisis situation may be such as to prevent these shipments from physically reaching their destination (by blockade, for example). Political and economic constraints usually make it impossible for most countries to be totally independent of external sources.

The political state of the world today, as outlined earlier, makes it mandatory to maintain a balance of forces between the two superpowers on a global scale, and between the two major military alliances at a more regional level. Maintaining this balance is an expensive business. Yet no country can take the risk of slipping behind its neighbours and thereby weakening its chances of maintaining peace and stability in that area.

Military research and development establishments have a role to play in helping to achieve this balance in an economically feasible manner. In the absence either of total disarmament or even significant mutual force reductions, the strength of national defence forces will continue to be kept at high levels. The only way to reduce spending is to try to improve the cost-effectiveness of the equipment. This can be done by incorporating new technological innovations into weapons which can result in, say, energy savings, fewer operators required, ammunition savings through greater accuracy and efficiency, and greater survivability of the entire, active military machinery.

On obsolescence and economics

Most of the industrialized nations conduct military research and development, at varying levels of importance depending on their particular preoccupations. Even if it is extremely expensive for a country to develop and subsequently manufacture a new weapon system on its own, a nation will still have a skeleton staff working on this particular problem in order to keep up with general technological progress. Economic constraints have forced several allied countries to pool their research resources in order to carry out a development programme to fruition.

As older systems become obsolete, they need to be replaced by new and more efficient ones. Sometimes budgetary restrictions make it necessary to develop inexpensive, but technically up-to-date, improvements to the older systems in order to extend their useful life.

Some Third World countries, particularly those possessing an industrial base, are finding it necessary to create military research and development facilities. They have to spend their scant resources judiciously, looking for economies wherever possible. Since many of these countries cannot produce their own high-technology weapons, they need to obtain these from friendly nations. They cannot afford to depend solely on manufacturers' claims; they need to evaluate a new weapon system thoroughly themselves in order to be sure of buying the most suitable equipment. For this, they require specialists familiar with the latest technology available.

Many countries thus maintain small research teams which keep abreast of all the latest developments.

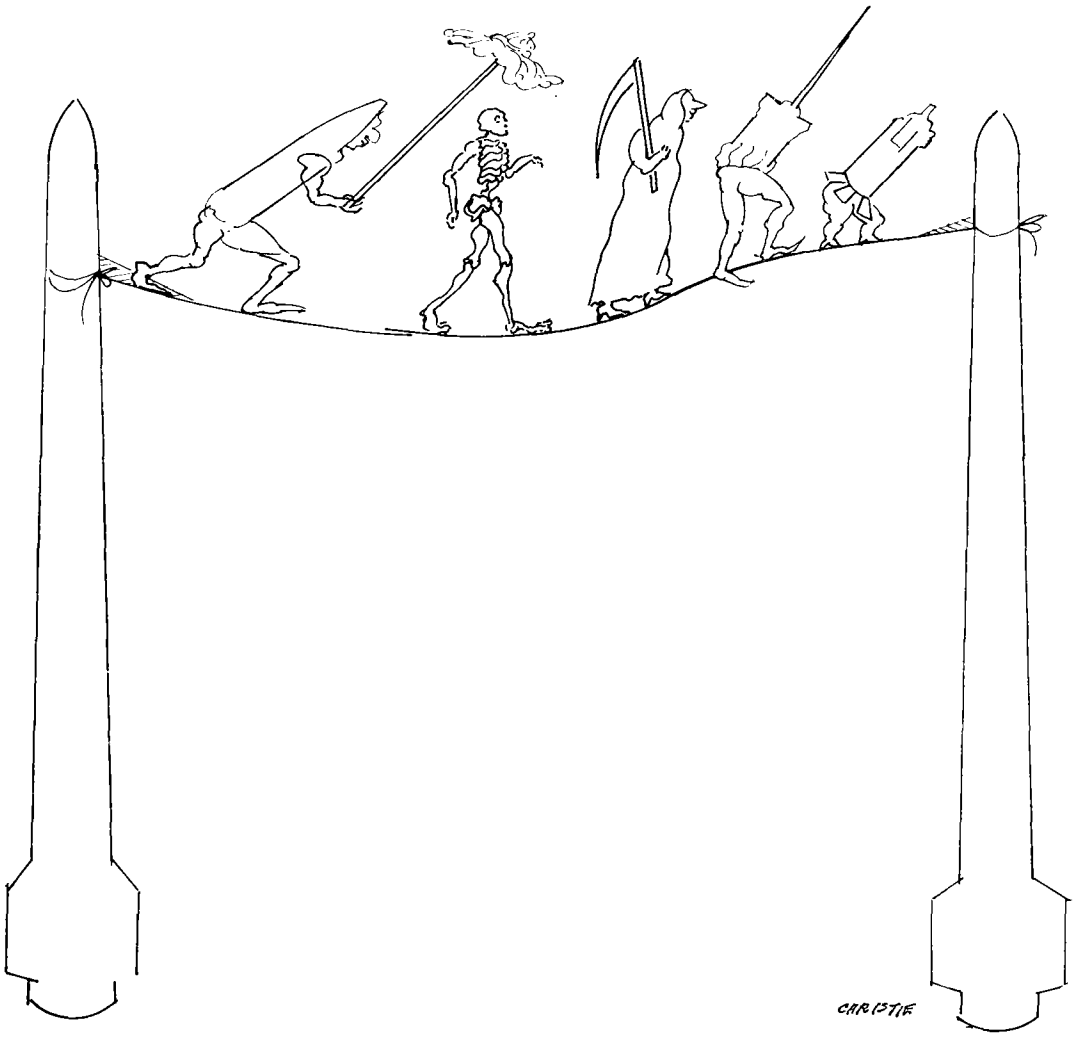
Economies can also be made by substituting locally available materials and indigenously produced components. Research-and-development establishments usually devote much effort to finding ways of increasing the indigenous content of imported items, and making modifications to improve their performance under local conditions or to extend their service life.

In many cases, weapons offered by industrialized nations are extremely expensive and far too sophisticated for (a) use by many Third World armies or (b) for the level of threat anticipated. The research and development establishment in a Third World country can thus be used to develop simple but effective equipment for local production. This can save the

country quite a bit of foreign exchange in the long term which can, in turn, be channelled to other humanitarian needs.

Technological overspill

Military research and development efforts do not only produce weapons of death, as has often been said. Since it is so crucial for national security, the field of defence is the one which often unfortunately gets the highest priority. It is therefore possible for military research organizations to maintain highly qualified staff sufficiently disciplined and motivated to come up with new developments in a hurry. Although many new technologies are developed primarily for military use, they have also greatly helped in the civil world. During the last decade, military research-and-development efforts have produced major technological breakthroughs in, for example, laser technology, high-speed digital data processing, micro-miniaturization, fibre optics, night-vision equipment, and communications in general. These could have taken years longer to be realized if the military imperatives did not exist.



Lasers are extremely useful on the battlefield for accurate range-finding and target designation. The latter allows so-called 'smart' weapons to be guided to their targets with great precision. This makes the weapon system more effective and reduces the number of missiles or bombs to be deployed against a given target. Since these weapon systems are very expensive, their potential can lead to considerable savings. These advantages have led military researchers to devote considerable time and effort to this technology, to the point that the state of their art is now very advanced. Important new applications have been found, however, for lasers in non-military fields. They are used in medicine to perform complex and delicate operations that were hitherto impossible. They have also shown some advantages over traditional transmission of communications; they are now being used for this application.

Satellite technology has progressed rapidly, primarily because of the numerous military applications envisaged. Today's satellites offer the best means of strategic reconnaissance, and are vital to maintaining the balance of power between the Soviet Union and the United States, particularly by keeping an eye on the growth of either side's nuclear force. Apart from helping to maintain world peace, satellites have many useful civil applications. In meteorology, they are used to provide advance warning of climatic changes and so help avert disasters. In communications, they are placed in geostationary orbits above key areas of the earth, and function as telephone, television and data-relay stations to maintain worldwide links. Satellites have also been found to be very useful in uncovering new resources of the earth.

Navigation, space research, and lasers

Navigation problems have been greatly simplified by the use of satellites. The Transit Satellite Navigation System was originally a military programme to help United States Navy ships to navigate. Transit was subsequently offered to, and is still widely used by, the world's merchant fleet. The NAVSTAR Global Positioning System is a new satellite-based navigation system which is in the process of being implemented, initially for military use. When it is offered to civil users, as is planned, the system will provide extremely accurate data on time and geographical location to anyone having an appropriate receiver. This system should prove to be of invaluable assistance to ships, aircraft and even automotive vehicles all over the world.

The 'space shuttle', which is causing so much excitement among the world's scientific community, is expected to provide the opportunity to conduct innumerable experiments and help fundamental research to make further great leaps forward. Yet from the outset, the Space Shuttle Programme has been an American military one.

Space restrictions on board satellites, aircraft and missiles accelerated the development of microminiature components. At the same time, vast quantities of data were required to be processed by these components. This brought about the development of microprocessors and advanced high-density electronic packaging techniques. A major American military programme aims to produce a range of very-high-speed integrated circuits. Much of this technology is available for commercial and civil use, and a number of useful applications have been found. Pocket calculators and mini-

computers are now commonplace, while farm tractors, washing machines and other household equipment now feature microprocessor-control.

There are countless other domains where new technologies developed initially for military applications have subsequently proved extremely beneficial to civilian life. (It is not possible to discuss them all here.) Admittedly, these developments might eventually have come about, but it is a fact that their appearance was stimulated considerably because of the pull of military requirements.

What alternatives?

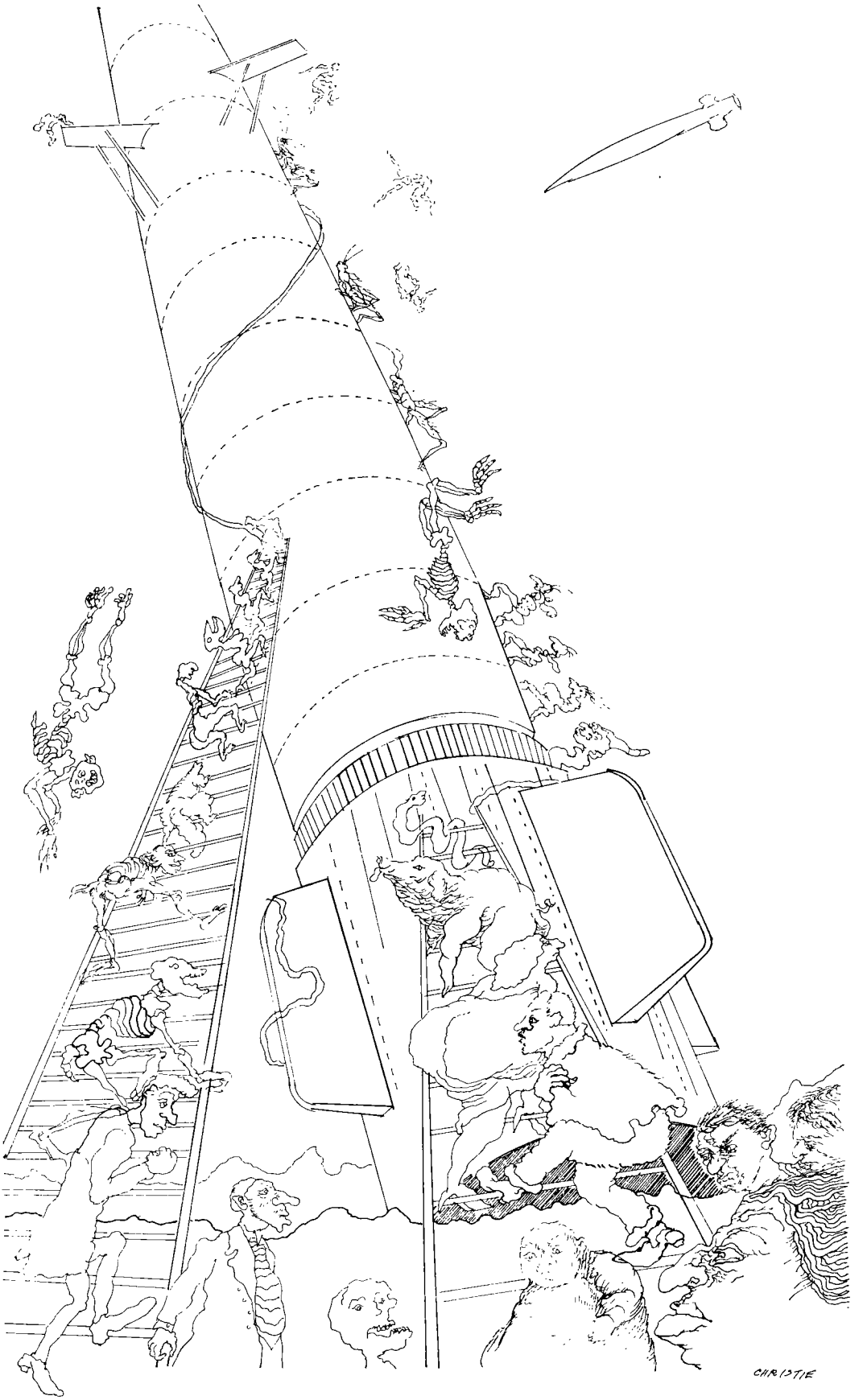
It is not my intention to promote military spending nor to try to justify military research and development. There can be no doubt that the defence budget imposes a severe burden on a country's economy. Many countries cannot afford to arm themselves the way they do, or devote so much of their resources to military research and development. Yet they continue to do so and, in many cases, they are allocating more funds each year for defence. It is unfortunate that world conditions have made defence, including military R&D, a necessary evil, and forced countries to review their other priorities in favour of armaments.

How can this trend be reversed? It is not easy to change human nature, but a serious and sincere attempt has to be made. Since total disarmament is not truly a realistic and feasible solution, other avenues must be explored. Since defence budgets cannot be completely eliminated for the foreseeable future, one possibility is to try to reduce these and, if possible, put an end to military research and development.

It may be (relatively) more possible to achieve mutual force reductions, with strict international controls to ensure that agreements are not broken. Each country could perhaps be forced by international agreements to reduce the size of its armed forces to a level just sufficient to guarantee national security. Moreover, development of new weapons could be forbidden, and only existing equipment allowed to be built to replace out-of-service equipment. This, too, seems highly improbable in present circumstances. In any case, what would be the consequences for overall technological progress, given the overspill effects described earlier?

The frightening growth in military spending, and the spectre of an endless arms race, have already led to some action along the lines mentioned above. Talks are being held on mutual balanced force reductions in Europe. Tentative agreements have been reached between the Soviet Union and the United States on the limitation of strategic arms. There has even been an attempt, albeit abortive, to limit arms sales by the two superpowers to Third World countries.

There is still a long way to go, however, and the road is studded with obstacles. Much patience and goodwill are required, and ideological, racial and religious differences need to be tempered. Most countries need to make a fresh beginning and again reassess their basic priorities. A host of pressing and worthy causes are waiting to use the vast sums of money and other resources now being devoted to the development and purchase of arms for military use. ■


CHRISTIE

A university researcher tries his hand at poetical dialogue, combining some thoughts of Albert Einstein with newspaper headlines during wartime.

impact *of science on society*, Vol. 31, No. 1, 1981

Anathema

Richard J. Ruffini

'Gentlemen, concern for man himself . . .'[1]

READ ALL ABOUT IT! READ ALL ABOUT IT!
HIROSHIMA BOMBED![2]

'Gentlemen, concern for man himself and his fate
must always . . .'

60 % OF HIROSHIMA WIPED OUT! 10.6 Sq. Km
of City Laid to Waste and Ruin! 1 Bomb = 20,000 Tonnes of TNT!

'Gentlemen, concern for man himself and his fate
must always form the chief interest of all
technical endeavours . . . never forget . . .'

NAGASAKI BOMBED! Target Smashed in Split
Seconds Because of Concussion!
Smoke Seethes 12,000 Metres

'. . . never forget this in the midst . . .'

JAPANESE SURRENDER!! JAPANESE SURRENDER!!
ALLIES VICTORIOUS! ALLIES VICTORIOUS!

'. . . never forget this in the midst of your diagrams and equations.'

Notes

1. Quotations adopted from A. Einstein in R. Lynd, 'Knowledge for What?' and V. Hinshaw, Jr, 'Einstein's Social Philosophy', in P. Schilpp (ed.), *Albert Einstein: Philosopher-Scientist*, p. 649, New York, Harper & Row, 1959.
2. Newspaper headings adopted from the *New York Times*, 7, 9 and 15 August 1945, Sec. 1, p. 1.

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Weapon development, from simplicity to complexity

Thought of nuclear war enters only sporadically into our popular consciousness; but in the world of defense analysts, it has never gone away. There it is an obsession, a disease. Because it is intellectually neater, more engrossing to the mind, to speculate on theories of first strikes and limited nuclear war than to fret about engines for tanks, the 'best' minds in the business are drawn toward this flame. . . . Conclusions about fighter aircraft are always subject to factual substantiation or disproof; but theories about how [the opponent] might react to a nuclear alert can be proposed, can make the author's name, and can finally be debunked without once touching ground. It is the modern equivalent of medieval theology, and it determines much of our defense budget.

James Fallows
Atlantic Monthly,
October 1979

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Brazil is perhaps one of the two most advanced 'developing' countries of the world, a nation currently enjoying an unprecedented economic flight which promises to bring it quickly into the late twentieth century. In this article are reviewed the military posture which Brazil is acquiring through the growth of its domestic armaments industry and of its international commerce in arms, and the new applications of scientific technology that this growth implies. The author passes in review the overall significance of the 'Brazilianization' of the country's military industries.

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The case of Brazil: fortress or paper curtain?

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A case of forced expansion

The arms dealers seem to enjoy the present international situation, as the flow of military equipment grows proportionately with international tension. In reality, neither détente nor economic crises impede the alarming expansion of this commerce, as the world arms market exceeds an amount of $400,000 million. Brazil is taking part in this internationalization of armament, so in the present article I shall examine particular aspects of the Brazilian arms production, arms trade and how it is also stimulating world trends in this respect.

Brazil has assumed since the coup d'état in 1964 a 'security and expansionist' model of development, pushing for a stronger defence system as well as domestic arms production. More recently, Brazil has promoted a policy of arms trade with countries in Latin America, Africa, the Middle East, Europe, Asia and even the United States. It is known that domestic arms production and the arms trade are the two main ways by which a country can acquire military power. In addition to these, Brazil is becoming a nuclear power and has assumed in the last fifteen years an expansionist posture in Latin America and Africa.

Based on these premises, should we consider Brazil an emergent military power both at the regional and international levels?

The ruling power that assumed the country's administration in 1964 developed, as a model for its foreign policy, geopolitically based foreign trade and a 'big-power' game of expansion. The military leadership, at the onset of its power, established the National Security Doctrine as a universal target in order to control not only the nation as a whole but essentially the priorities and organization of civil society and its process of social development. Security came first, and economic growth was orientated towards the internationalization of Brazilian resources. Trade was then emphasized, to integrate the country into the world market. Economic association with the United States and co-operation with the highly industrialized countries were considered a privilege—a privilege because of the accessibility of the latest technologies, mainly in the sectors of heavy industry, communication, energy, and defence. The mood was to boast about great power, as clearly put by a leading Rio de Janeiro weekly magazine, *Manchete*: '... after Mirages [the reference is to fighter aircraft] almost inevitably there will come Phantoms, modern tanks, Polaris nuclear-powered submarines, aircraft carriers, satellites, rockets and the atomic bomb itself.'[1]

Strategically, the ruling authority called for a priviliged status for Brazil in the international economic system. Concretely it asked for a tactical and selective alliance, since this alliance could bring benefits to the country in economic and security terms. But in reality the new model, which was sought to reverse the national and popular projects under way before 1964, left the nation more vulnerable and aggravated demographic conditions in Brazil.

The strong state

Thus, on the one hand, we see a vulnerable nation open to international capitalist accumulation and, on the other hand, we see reinforcement and centralization of the state in the political, economic and military domains. With a divorce between nation and state over the past fifteen years, contra-

dictions, frictions and oppositions have been frequent. Meanwhile, as the cold war was in relative decline, new room for manoeuvre gave emerging leaders power, a chance to participate in world affairs. The Brazilian ruling élite focused on rapid economic growth, expansion and diversification of foreign trade, industrialization of new sectors (previously peripheral) and the strengthening of the state's productive centre. In addition, scientific and technological advances were important for the expansion programme the ruling class wanted to undertake. The state fortified itself more and more and became the instrument of a 'viable peripheral capitalism'.

The viability of such a project allowed the state to broaden its actions, combining these with its traditional repressive role. Besides this specific form, the state assumed a new style of bureaucracy. The role played by technocrats as the new demiurges of the Brazilian economic miracle was increased.

To maintain a global planning, stability and strong centralization (ever threatening the Brazilian federation) were required to ensure an international flow of investments and to proceed along a route of accumulation. This type of development has resulted in an amalgamation of a repressive apparatus—under strict military control—and an entrepreneurial public sector. The latter functions as a selective gate through which capitalism can pass in order to industrialize new 'islands' of growing economy. What seems peculiar in this process is the 'internalization' of the international capital within Brazil's market. In this way, the state works as the office-holder of development in association with transnational corporations. One observer has concluded that there is a 'mutual indispensability between this form of state and international capital, which possesses the technological and financial requisites to undertake a deeper development'.[2]

Politically, the state acts to prevent multinational firms from single-handedly taking over the strategic sectors of the economy and their most dynamic branches. This has led the state's apparatus to expand its functions and thereby use 'national resources' as a means to bargain with the international system. Thus, the state, as the strong tool of this process of accumulation, became a typical, productive, economic organization. After fifteen years, the result is that of the state battling for some kind of second phase of accumulation. The search now is for highly advanced technology to overcome the obstacles which, at the international level, control the transfer of this technology.

Brazil as part of an international arms competition

The development of the Brazilian military industry is paralleled by the ascending curve of world militarization, increases in defence appropriations, the arms trade and armed conflicts.[3] It seems also that the Brazilian military industry is, to a great extent, the result of capital accumulation occurring over the last two decades. This followed the pattern assumed by the state in association with private big capital, both national and international. The situation has evolved into a conflict between an old conception of dependent development and the present (and more complex) modes of transferred technology, in which there is a close association between the state and multinational capital. The most explicit example of this is military technology.

There is a link between the Brazilian style of development and its recent buildup of military defence. As Brazil expands and integrates itself into the

international market, demands for a higher technology, control of strategic resources and participation in the world arms market constitute the policy implicit for domestic arms production. In addition, Brazil's military buildup is reinforcing the old geopolitical conception of the country's expansion throughout the South American continent.[4] This is especially true in the area of the River Plate Basin, where multimillion dollar industrial programmes are being executed.

Since a tremendous security belt is required to protect Brazil's future nuclear power, a strong military defence will be needed to integrate the whole. Besides, Brazil's positions in relation to international nuclear policy has been critical: Brazil has not signed the Non-Proliferation Treaty, and it has maintained a critical view of the superpowers' control of international energy policy. It signed the Tatelolco Treaty—concerning the Latin American Nuclear Free Zone—but, up to now, Brazil has not ratified some of its clauses, thus leaving considerable freedom to develop nuclear weapons. Brazil signed a secret nuclear agreement with the Federal Republic of Germany, from whom it hopes to obtain the full panoply of nuclear technology. Other 'connections' can be identified with Brazilian military production, such as the tensions existing around the southern cone of Latin America, the recent Amazon Basin Pact (signed between Brazil and seven bordering countries), and the South Atlantic link with Africa.[5]

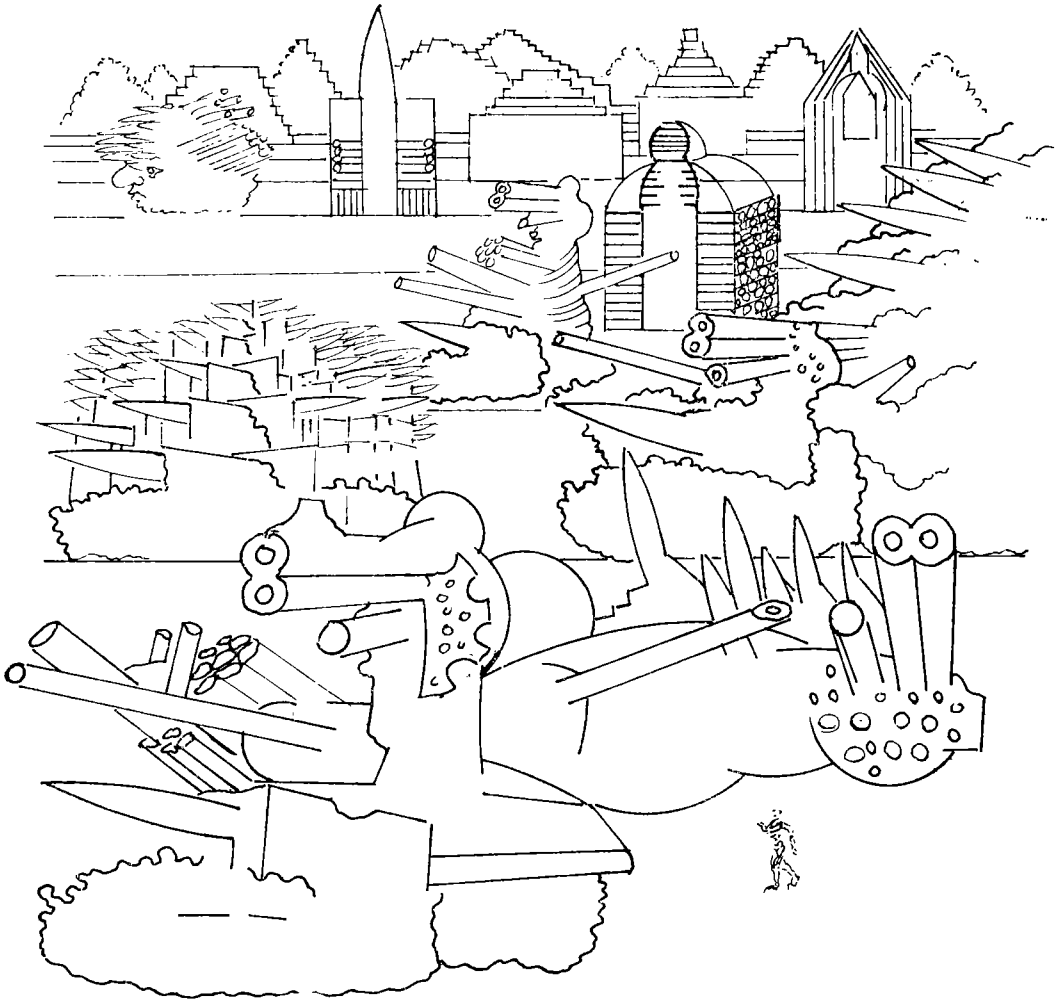
Here some questions arise. How will the defence industry become an issue of national debate, especially within the armed forces and in Congress? Will this be a question of sensitive nationalism in the face of a threat (real or elusive), which would result in a weakening of the international status Brazil has claimed to have? Will the defence industry receive national support, leaving the country a free hand to produce and protect highly advanced technology against interference by foreign and transnational corporations? Will the end of authoritarianism and the inauguration of a democratic regime be the expedients for changing, reversing and demilitarizing Brazil's military buildup trend? Or, after the military's withdrawal, will there be compatibility between democracy and increases in military expenditure as a world trend? Finally, how to control the arms trade through efficient policies both at the national level and at the level of arms trade?

Brazil's industrial military structure

Mobilizing resources for military industry

The Brazilian armed forces, institutionalized during the Paraguay War in 1860, have passed through different phases of organization and operation. Since its independence in 1822, Brazil has been engaged in five foreign wars, the major one the Second World War, when in exchange for granting military bases to the United States, Brazil received a steel plant and sent 20,000 men as an expeditionary force to fight in Italy against fascism.[6]

Traditionally, Brazil's armed forces were supposed to observe a policy of defence rather than offence, concentrating on the task of protecting its frontiers against eventual enemies. During the 1960s—at the apex of the cold war—the main attention of the Brazilian military became focused on internal security and counter-insurgency, with the United States' strategic atomic umbrella guaranteeing protection to the hemisphere and the world. Hypothetical external threats were secondary, and the order of priority was



given to the acquisition and development of arms. The Brazilian armed forces imported most of their armaments from the United States. Locally, Brazil produced light weapons and ammunition, even though it used foreign technology. Consequently, for many military officials, the necessity to become self-sufficient in arms production was a sensitive issue. The Viet-Nam war created a gigantic need for supplies during the 1960s, at which time the United States imposed restrictions on arms transfers to Brazil and other countries. These restrictions made it necessary for the military in Brazil to turn to Europe, a more 'secure' arms market. For the period from 1967 to 1972, Brazil's purchases were more than 40 per cent of the total sold to Latin America.

It was after 1967 that the Brazilian armed forces began to modify their view of a new defence system. Contributing to a new pattern was Brazil's relationship with the international system in both bilateral and multilateral terms, including production and trade in arms. After 1972, new relations with Africa called for a much larger external defensive capability.

Thus, progressive prominence was given to domestic arms production, through the re-equipment and the 'modernization programme' set up by

the military establishment.[7] It has been said officially that 'nationalization' of armaments will enable Brazil to be less vulnerable in a world crisis, particularly with the United States' world supremacy diminishing noticeably. The Brazilian armed forces, aware of the situation, asked for more defence appropriations and substantial finances to move in the direction of a strong military industry.[8]

In less than ten years, from an antiquated military system, with seven factories producing guns, gunpowder and ammunition, Brazil's military industry in 1979 ranked fifth on the list of export manufacturers. There are now more than fifty private and state enterprises employing more than 100,000 workers, with sales at about $5,000 million. As expansion projects developed with the association of private capital and state enterprises, Brazil made important advances in the production of armaments. The motivation was partly attributable to the desire to move away from reliance on the United States, partly conditioned by the technological progress that Brazil had achieved. The effort has been given new stimulus with the signing in 1975 of a new law creating Industria do Material Bélico do Brazil (IMBEL), or Brazilian War Material Enterprise.

IMBEL's effort to concentrate

IMBEL is a state-owned holding company with the possibility of becoming largely self-sufficient in arms, and with a capacity for exports. As a holding company, IMBEL has the function of linking the country's military sector with private industry and to control the seven most important factories supplying military material. The Industria produces thirty-one basic items; it has a budget of $6 million (1980), of which $1 million are allocated for research and development (R&D).

IMBEL's policy was designed to meet competition in the national arms market and, later, to enter into the international arm sales. The initial plan was to increase private participation in the development of local industries. But IMBEL requires that foreign entities, interested in establishing production lines in Brazil, bring technology, capital and foreign customers along with them. At first the re-equipment programme was geared to the replacement of old (Second World War) material; but, in reality IMBEL was worried about the economic problems that the defence industry was facing in the search for more self-sufficiency in major equipment. The National Security Council (CNS) is planning new legislation for the military-industrial sector, as to both implantation and arms exports. This will produce changes in (a) the national export policy of military equipment and (b) in taxation (tax reductions). Up to now the military industry's export policy was guided by a secret document produced by CNS that is now considered outdated by the military authorities and the private military industry. According to the co-ordinator of Sectoral Group 7 (Council of Industrial Development—CDI) at the Ministry of Commerce and Industry, there is urgency in creating special legislation for the military industry because of its particularity. He said:

> The war industry is perhaps the only option the Armed Forces have, at their disposal to produce the armaments that they need. War material polarizes the general development of industry and it brings to the country an advanced technology. Notwithstanding, it must orientate part of the production to the external market which is highly competitive.[9]

There would be new propositions covering four fields: (a) reduction in the industrial product tax (IPI) and a new tax on imported goods; (b) rapid depreciation of national equipment; (c) IPI credit for national equipment; (d) a right to preferential financing by the governmental banks. There are divergent opinions among the military about which policy will be more effective to bring the military industry to self-sufficiency. In the CONCEM (Conselho do Chefes do Estados Maiores—Council of Chiefs of General Staffs of the Armed Forces) the debate is fierce among opposition forces regarding rigidity and tolerance of the degree of nationalization of war industry. For some military officials, there should be no obstacles to the implantation of foreign companies in the sector. For others, they question the validity of the presence of foreign capital in the national war industry. Yet, going beyond mere equipment replacement, IMBEL plans to achieve a more ambitious production of arms consistent with changes in views of the national security doctrine.

New components policy

In observing the policy of importing only the necessary quantities of war material (to keep the balance in favour of domestic production), IMBEL is seeking patent rights and software technology with maximal control of capital participation. The import substitution policy in the military industrial sector began in 1968 when the armed forces planned to reproduce exactly equipment bought from the United States. But that experiment failed. At the beginning of the 1970s, Brazil imported $50 million annually in arms. But in the military budget for 1978 and 1979, this amount was divided by three and the import list was restricted to electronic equipment, combat jets and four frigates (bought from the United Kingdom in exchange for blueprints of two other frigates to be built in Brazil). A new policy was then implemented, so that private industry should take into account locally available civil products. Thus, for example, a new army missile would use components from eight suppliers fitted to the hull of an old American tank. Only one plant co-ordinates the whole project, organizes the assembly line, and signs the patent-licences of the adapted vehicle.[10] Intensive use of civil components is also part of the strategy to conquer an external market.

Brazil's expansion in its own production of armaments, its co-production association and joint ventures with foreign firms raise many questions in the military, technological, political and diplomatic areas. The possibility of Brazil competing with the United States in arms supply will complicate the relationship between the two countries even more. The United States imposed restrictions upon Brazil in terms of human rights demands, attached to the military aid given by the United States Congress. The immediate reaction on Brazil's part was cancellation of four military agreements in a move that the United States considered as an end to all formal military co-operation between the two countries.[11] Along with other restrictions imposed on arms sales and credits to military regimes in Latin America, the United States opened the way for Brazil to begin exporting extensively, without fear of political repercussions and free of ideological ties.

Although there is now considerable expansion and diversification of its defence industry, Brazil is still far from becoming technically, industrially, and financially self-sufficient. Over the long term, shortcomings and constraints might run counter the easy situation that Brazil's defence industry

is currently enjoying. Economic recession and international competition are, at least, two immediate problems it will face. Besides, there is the fact that the country is suffering from growing pains in the political transition towards democratization; this will also determine the role of Congress and the autonomy of the military-industrial complex.

What follows is a study of two of the most important areas in the Brazilian military buildup. Without neglecting other areas (such as the navy's expensive programme and the battle for electronic technology) we are going to focus on air force and army projects.

In the case of the air force our attention turns, first, to its leading position *vis-à-vis* technological development and, secondly, to its strategic role in the country's air defence system, then, thirdly, to the policy of aircraft production for which EMBRAER (Brazilian Aircraft Enterprises) was created. We shall examine EMBRAER's policy in terms of industrial production and international market performance.

It is valuable to study the army's traditional role in the Brazilian political arena, its hegemonic position within the armed forces and, finally, its capacity to renew its concept of arms production. Well worth a close look is the connection between the general modernization policy of war material (which was planned by the army) and the birth of private military-orientated industries that have begun to produce heavy equipment, as in the case of ENGESA (Specialized Engineering Enterprise), Bernardini, Biselli and Jamy.

Air defence system and aerospace development

Contrary to the past (when the air force was under the army's control, without effective action of its own), the modernization programme—carried out autonomously by the Ministry of Aeronautics and its affiliated industrial complex—will have considerable impact on Brazilian military strategy and structure. The air force will have a key role in the re-equipment of the armed forces. This situation is because the Centro Técnico da Aeronáutica (Technical Aeronautic Centre), established for training aeronautical and aerospace personnel and for conducting aerospace R&D, forms a broad conglomerate of institutes and research centres.[12] Secondly, the situation guarantees advances in technical skills (design and engineering) and industrial development, creating an aggressive programme of modernization of equipment. Thirdly, there has developed an outgrowth of the aircraft industry (with EMBRAER and other small private industries), ultimately penetrating the international market—in terms of arms trade, technology, and technical information. Apart from supersonic fighters, the air force is building its own fighter-bombers and acquiring sophisticated ground-control radar and the essentials of an air defence system, including ground-to-air and air-to-air missiles.[13]

By 1975, the total modernization cost was estimated at $350 million. Since then Brazil has devoted much more in absolute terms to air defence than any other Latin American country. In connection with the re-equipment programme, the Ministry of Aeronautics signed a $70 million contract with Thomson-CSF (France), a joint venture for the construction of an air-traffic control and defence system to cover the Brasília–Rio de Janeiro–São Paulo triangle. An extension of this system will cover Rio Grande do Sul and the southern borders of Brazil, mainly around the Plata Basin. The purpose

there is to control the entire area of industrial concentration where the Angra dos Reis nuclear plants are under construction and where the world's largest hydroelectric dam, Itaipú, is also being built.

The real significance of the air force re-equipment programme is the fact that it is much more technical and modern than that of the army and the navy. The Brazilian Air Force has more power today than ever before; it is moving not only towards a modern air-defence system and into aerospace development but towards an autonomous air force.

EMBRAER's aircraft programme

In 1966, a report entitled, 'Science and Technology of the Ministry of Aeronautics' analysed the failure of various attempts made in Brazil to produce aircraft. Basically, the report said, as soon as the government removes incentives, the private company simply dies; this weakens, in turn, a potential market. Thus, private industry—in the early stage of development—does not have the motivation to invest in aircraft production. The report concluded that (a) only the public sector is able to promote the country's aircraft industry and, (b) considering the desire that the final product be truly Brazilian, that the software components be nationalized. On the contrary, if the industry depends on foreign sources, the country would remain in debt with heavy interests, forced to import equipment semi-finished or finished, and it would be limited to the methods of inadequate production.[14]

Because of the motivation of supporting the development of a national aircraft industry, EMBRAER was founded in 1969.[15] The Brazilian Air Force set a policy of aircraft production, one elaborated at the Aerospace Technical Centre (CTA). Finally the government approved the idea of building a new aircraft model, 'adapted to Brazilian conditions'. After ten years of production, EMBRAER has turned out an average of forty aircraft a month, making, in all, eleven different types of aircraft in fifty separate models. EMBRAER is considered by international specialists to be the sixth largest aviation company in the world, outside the United States (Fig. 1).[16]

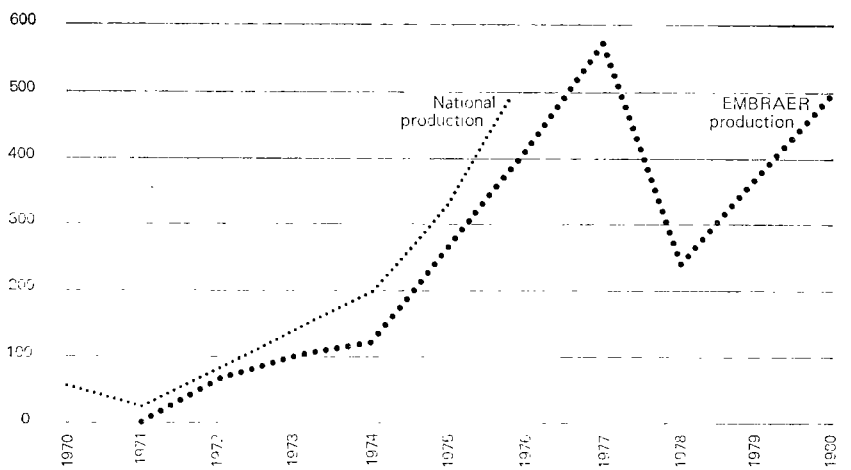


FIG. 1. National and EMBRAER aircraft production, 1970–80 (in millions of dollars). After EMBRAER and others. The figure for 1980 is an estimation.

Besides its best commercial plane, Bandeirante, EMBRAER's aircraft lines include: the Xavante jet trainer, based on a design by Macchi of Italy; a joint venture of a ground-attack and support aircraft which will replace the Xavante; EMB–12X, a family of three medium-size twin-turbo-prop aircraft for general purpose; the series EMB–121 Xingu, EMB–123 Tapajos and EMB–120 Araguaia, currently in the works. The newest models were presented in 1980: the EMB–312 turbo-prop aircraft for military training and the EMB–120 Brasília for carrying passengers.

In 1974 EMBRAER, with government support, signed an agreement with the Piper Aircraft Corporation (United States), allowing the Brazilian company to assemble models that had been previously imported. The accord provided for an increasing percentage of locally made components and gave EMBRAER the right to modify the aircraft's design to its own specifications.[17]

Another model is EMB–201 Ipanema, an agricultural aircraft designed and developed under the Ministry of Agriculture's specifications in three different versions: Carioca, Corisco, and Minuano.

EMBRAER has become an alternative in the general aviation market of the world. The company's struggle to develop an export market has been long and, in general, successful. The energy crisis has played a role in this success; as small planes became too costly to run, EMBRAER was well placed to fill the gap. The problem was to have its aircraft accepted by the industrialized countries. The company embarked upon an export programme and, so far, has placed its products in Latin America (Uruguay, Chile, Bolivia, Paraguay, Mexico, Venezuela and, soon, Peru); Africa (Togo, Sudan, Gabon, Nigeria, Mauritania); the Middle East (Iraq); Oceania (New Guinea and Australia); Europe (France and the United Kingdom), and in the United States.

The technology which drives this industrial complex (one which includes more than 250 component suppliers) is part of the 'Brazilianization' process. The big issue is the control of technology, since the absorption of know-how (hardware and software) is still in the hands of a closed 'club' of industrialized countries. Another important aspect of aircraft production is its labour force. Of the final price on a product, 50 per cent is contributed by labour. EMBRAER has claimed that 95 per cent of its labour force is Brazilian and only 5 per cent foreigners or naturalized Brazilians. According to EMBRAER the nationalization percentage rate of its products is as follows: Bandeirante, 57; Xavante, 40; Ipanema, 80; Xingu, 70; and EMBRAER/Piper models, 40–5.

While EMBRAER's own aircraft have been designed, engineered and built in Brazil by Brazilians, many of the components and avionics used are supplied by multinationals such as Pratt & Whitney, Lycoming Corporation and Continental (engines); Collins Radio Corporation, King, Narco and Cutler-Hammer. Alcoa supplies alloys, while Bendix furnishes brake parts and avionics. EMBRAER estimates that by the end of the century, Latin America will account for 40 per cent of the world's aviation market and Brazil will, in turn, account for half of the continental total. The EMBRAER plan is to introduce more new models, sharpen international competition, enlarge its trade sector in order to provide a greater share of the components and a larger portion of the purchase price. The company is well involved in Brazil's military-industrial complex, meshing both the government's desire for a national industry with its national security objectives.

Freezing aircraft imports

As economic difficulties came into Brazilian life after 1974, and restrictive financing interest rates were imposed by the government in 1977, EMBRAER's production and export slowed down. The Air Ministry said that in order to achieve a higher degree of Brazilianization, the aircraft industry would not order foreign military aircraft, although no time-limit was set. More recently, it has been indicated that a time-limit of 1982 would be set. Policy emphasized that the country had to 'avoid imports of aircraft which could damage our technology'. With a heavy burden assumed by the purchase of American F-5s and sixteen French Mirages, the decision was made to postpone large purchases until all payments for the earlier contracts have been made.

By 1977, EMBRAER was preoccupied with the amount of unsold inventory—numbering some 300 units—more than twice the normal—of light aircraft used in agriculture, worth about $27 million. EMBRAER's operating capital at that time was $15 million, and the stock represented almost 50 per cent of the orders on its books. Following the restrictive financing interest rates imposed for economic reasons in 1977, EMBRAER had to cease production of this aircraft (Table 1).

TABLE 1. EMBRAER's production rates per month and unsold aircraft, 1977–78

Model	1977	1978	Unsold
Carioca	7	2	90
Corisco	8	2	25
Minuano	5	1	
Sertanejo	3	1	
Seneca	5	1	
Navajo	3	0[1]	45
Ipanema		1	30

1. Production was halted in January.

Source: Aviation Week and Space Technology, 21 August 1978.

Although interest rates have been lowered recently, other factors have inhibited sales, such as strict operational requirements, EMBRAER's loose sales organization, and the high initial and operating costs of aircraft. Added to this was a reduction in agricultural credits and an economic recession; these have influenced the sharp drop in demand. However, EMBRAER predicted that the domestic market (which takes about 800 aircraft a year) will grow by about 300 as a result of new government-sponsored credit-sale schemes. EMBRAER, which sells 60 per cent of its Ipanema and Piper models to farmers (mostly in the southern part of Brazil), expects that a strong agricultural economy will ensure good general aviation sales.

The army defence industry

Brazilian history has been marked by the army's presence and involvement in political life. In the last decade, after the military coup of 1964, the army attained power over society; it has greatly influenced, almost without challenge, Brazil's development ever since. With a strong discipline and under

the umbrella of the National Security Doctrine, the army developed a 'manifest destiny' for national purposes. Until the Second World War, the army bought all its major weapons from the United States. After the war, although reliance on North American arms continued, Brazil's capacity for the development of weapons grew considerably. Holste, France, Fokker, the Netherlands and Federal Republic of Germany, P. Baumgartl, Austria, and Herstal, Belgium, influenced Brazil's domestic arms production by updating its weapons under foreign licence. The government gave the army the resources to create its own research centre in order to develop its own weapons. Then as now, the United States had reservations about the modernization of Brazil's army even though the United States was helping superior officers to become directly involved in Brazilian politics. The United States would prefer to see the army confined to an internal counter-insurgency role and, to accomplish this, it developed a huge military programme of sales, aid, credits and training.

Large expense is a major factor of modernization. The army has bought four batteries of missile launchers from a consortium made up of French and Swiss arms manufacturers, plus the Roland (French) missiles and the Cobra from the Federal Republic of Germany. Ground efforts are to be supplemented by those of the navy, with a support brigade of marines that would be transported in two landing craft manufactured in the United States. New armoured vehicles are to be introduced, as well as an airborne and five armoured or mechanized divisions with other, traditional infantry units scheduled for reorganization and re-equipment. It has a new parachute brigade, operational since 1977 with 7,000 men, transported with their equipment in forty-eight Hercules aircraft. The principle here is that the parachute brigade would be able to operate anywhere in South America within twelve hours.

ENGESA's participation

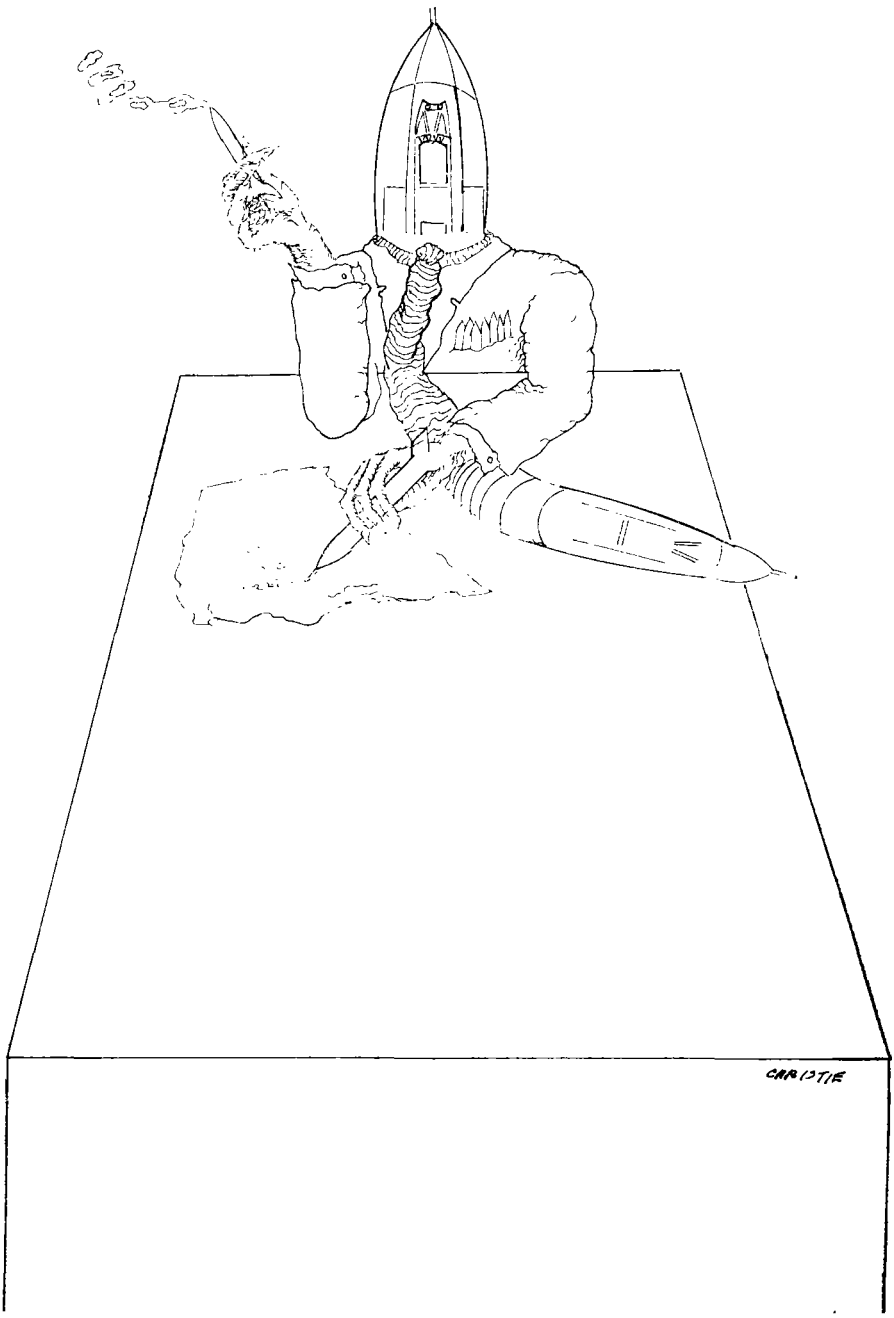
It was during the formation of the Group for the Mobilization of National Industry (GMI) that an independent traction system for each wheel of an armoured vehicle was designed and developed by a private Brazilian company. Immediately, both GMI and the army's specialized agency, the Institute of Development Research (IPD), became interested in the newly developed system. The army financed its development, first through its Department of War Material and later through IMBEL.

The evolution of the armoured car has been concentrated on relatively light-wheeled models capable of moving long distances overland—conditions typical of Brazilian territory or over desert sand, as in the Arab countries. The army's enthusiasm for such production was justified by the current strategic situation in Latin America, and the Middle East, which calls for vehicles of this kind rather than for tanks. At first, ENGESA began producing trucks with chassis and bodies made in Brazil but with engines and gears built under licence, either from foreign companies or imported local products (Mercedes-Benz). The idea of building trucks of original Brazilian design was based on two factors: the desire to be more independent of licence and imports, and to produce vehicles adapted to the very difficult road conditions in Brazil, especially in the Amazon. After ENGESA's good performance on the market, the company began manufacturing armoured vehicles of original design and manufacture, but with its high-technology components either

produced under licence or imported, or co-produced in the form of joint ventures.

The basis of ENGESA's involvement in the Brazilian army's programme and later, in export, has been its three originally designed vehicles. The first, Cascavel, was designed and produced in 1970 with the assistance of the University of São Paulo and the army Department of War Material. The second model, Urutu, is a fully amphibious, wheeled armoured car. It can operate on lakes or in river zones and at sea when fitted with special equipment. The Urutu is a basic model ranging from personnel carriers to internal security vehicles, and from anti-aircraft to armour-plated ambulances.

The Brazilian army has ordered many Cascavels since 1972, and the



Brazilian navy ordered special versions of the Urutu for its marine corps. The delivery of these vehicles was completed in 1973, and a year later the army ordered more Cascavels and several more Urutus. At the same time several hundred of these vehicles were exported, mainly to Middle East countries.

The third model is a modern wheeled tank considered as heavily armed as any wheeled armoured car built anywhere in the world. The Sucuri uses civilian components produced in large series, considered advantageous in terms of cost and maintenance. The latest is the Jararacà light reconnaissance vehicle that combines dimensions comparable to those of a jeep with all the advantages of armour plating. The Jararacà is still under construction.

Until now ENGESA has had a trade level of $120 million, but in 1980 it exported a total of $200 million, a sum equal to the value of its own production during the previous year. Its vehicles were involved in the last Arab-Israeli conflict, and among its customers are Latin American countries such as Venezuela, Chile, Colombia, Paraguay and Uruguay as well as nations in Africa, the Middle East and other parts of the globe.[18]

Conclusions

The Brazilian defence industry today produces all kinds of war material; it has become a large producer in the international circle of arms dealers, for many years occupied only by the advanced industrialized countries. One point of discussion is thus: does this effort to nationalize war industry coincide with the real emergence of a strong military power? Up to now, Brazil has been limited to the production of arms restricted to peripheral clients. And it cannot support a more highly advanced military system solely with internal demands. At the present time, the armed forces invest about half a million dollars annually for equipment renewal. For the local industry to survive, the only option is to export, a classical commercial expedient. This would explain the vigorous impulse of Brazilian defence industries, one also connected with a diversified industrial complex. ■

Notes

1. Quoted in *Latin America Digest*, Tempe, Ariz., Arizona State University, June 1973, p. 7.
2. G. O'Donnel, *Reflexiones sobre las tendencias generales de cambio en el Estado burocrático autoritário*, Buenos Aires, CEDES, 1975.
3. Increased military spending is one major indicator of the growing use of resources in the world for military purposes. Also, the international arms trade is one of the most alarming factors in world militarization, as shown by many institutions (United Nations, Unesco, SIPRI, International Peace Research Institute, Oslo, International Institute of Strategic Studies).
4. I examine this subject in my paper entitled, 'Brazil's Foreign Policy: The Last 15 Years', Research Paper Series, Institute of Latin American Studies, Stockholm, November 1978.
5. Brazil's authority has been systematically denied any participation in a military treaty or organization of the South Atlantic. In its own interests, Brazil has emphasized its commitment to the new African nations against apartheid and the status quo in Namibia. Recently, the Brazilian navy and air force have announced the installation of an air base on Trindad Island to control the intense traffic that flows through the South Atlantic.

6. Brazilian units formed part of the UNEF Corps in the Suez Canal crisis in 1956; the Brazilian air force participated in the United Nations transport operation during the Congo crisis in 1960; in 1965, a Brazilian general was appointed commander of the Inter-American Peace Force to support United States intervention in the Dominican Republic.
7. A military structure for wartime was approved by the present administration, unifying into a single command the three branches of the armed forces. This presidential decree was classified 'restricted' and was justified by the contribution it would make to the modernization of the military industry, *Jornal do Brasil*, 1 January 1980.
8. At that time Brazil was undergoing the so-called economic miracle at 10–12 per cent annually. The rising defence appropriations and arms orders were considered to impose no perceptible strain on its economy. The policy still continued to be applied in 1980.
9. *Jornal do Brasil*, 3 December 1979.
10. Cf. the case of Bernardini (an old Brazilian firm manufacturing safes), a leading enterprise collaborating with the Institute of Military Engineering to rebuild old American tanks, redesign their parts, and equip them with Mercedes-Benz diesel engines in order to transport three ballistic missiles each.
11. The Brazilian military cancelled a Brazilian-United States military commission, established in 1942 to co-ordinate efforts during the Second World War, rescinded a pact governing the use of imported United States armaments (1967); broke an agreement on participation by the United States in the aerial mapping of Brazilian territory. Following the refusal of a $50 million loan for the purchase of United States military supplies, Brazil cancelled a 1952 accord establishing a Joint Commission that supervised Brazil's purchase of American military equipment.
12. The following are the most important: Institute of Aeronautical Technology (ITA); Institute of Research and Development (IPD); Institute of Aerospace Activities (IAE); Institute of Aerospace Research (INPE).
13. The Mirage cost the Brazilian Air Force $30 million and plans were made for the purchase of the new Mirage V. But the cost of spare parts and engines, besides problems with logistic support and crashes, can be accounted for by the air force's regret about an earlier decision to procure Mirage.
14. *Jornal do Brasil*, 29 December 1968.
15. The state owned 14 per cent of the stock, 86 per cent of the subscribing capital being held by 126,000 shareholding companies, including American. By 1978, its capital was $37.4 million, employing 4,500 workers. EMBRAER serves as a good place for retired Brazilian air force colonels, who hold many of the top management positions.
16. The Brazilian private companies of Neiva, Aerotec, Aeromot and Motortec were associated with EMBRAER/Piper for assembly or production of components.
17. EMBRAER has set up a special unit, NAI (Nucleo de Articulação Industrial) in order to control the items imported and their nationalization (*Jornal do Brasil*, 11 December 1978).
18. ENGESA seemed to rejoice at the military's attitude towards United States military agreements. ENGESA's president said that the military cancellations 'were very profitable for the national industry. The accords were very good for those who supply the war material and receive dollars, but not for those who needed to create technology to assure independence in the sector. Through the military accords we were given a lot of garbage without the transfer of technology.' (*O Globo*, 24 May 1979.)

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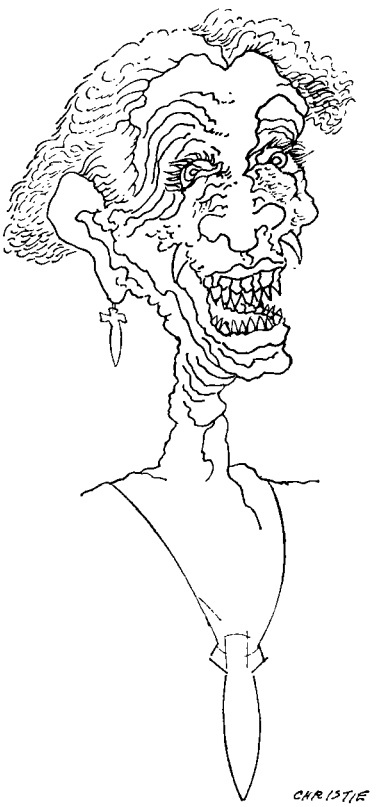
Two concerned scientists remind us that a little (technical) knowledge may (indeed) be a highly dangerous property. They pose the problem of how to deal with such a situation.

impact *of science on society*, Vol. 31, No. 1, 1981

Science, technology, weapons, and duration of the species

Marta Marcucci and Pietro Passerini



Dr Marcucci is assistant professor of geology at the Istituto di Geologia, Via Lamarmora, 4, Florence, Italy, while Dr Passerini is lecturer in physical geography at the same institution.

It is generally agreed that the fitness of the human species has been improved by the development of science and technology and, more specifically, by the extraordinary potential of man's brain (cf. 'Brain, Memory and Learning', theme of Vol. 28, No. 1, 1978, of *impact of science on society*). Technological progress has, indeed, lowered our rate of mortality, made societies less vulnerable to environmental adversity, and increased the earth's capacity to carry mankind. But, in the event of a general nuclear war, the development of the human brain could prove to represent what in biological evolution is called hypertely—evolution continued to inadaptive lengths that eventually result in a reduction of genetic fitness and may lead the species to precocious extinction.

Probability of the improbable

The decision by a state, especially a modern, industrialized state, to engage in nuclear conflict appears unlikely. But events improbable over a period of a year become much more probable and even virtually certain if the probability accumulates over a sufficiently long time. A 1 per cent probability each year leads to 63 per cent probability over a hundred years, 86 per cent over 200 years, and 95 per cent by 300 years (Fig. 1). If the spread of nuclear technology brings nuclear weapons within the reach of, say, fifty countries, then an annual average probability of 0.02 per cent that any given country will set off a nuclear clash suffices to justify the 1 per cent probability per annum.

If Hitler had had at his disposal any of today's doomsday machines—or even a sufficient number of 'rudimentary' bombs of the Hiroshima type—a planetary catastrophe would have been almost inevitable. Hitler was not a mistake unique in history and, in future, any insane dictator could have at his disposal a broad spectrum of nuclear, chemical and bacteriological arms. Moreover, it is easy to forecast situations in which not states but fools, criminals or political desperadoes might gain access to the means for mass destruction. So the figures we offer may be conservative.

The decision to start a nuclear war can be properly compared to suicide. The annual rates of suicide for males in European and other

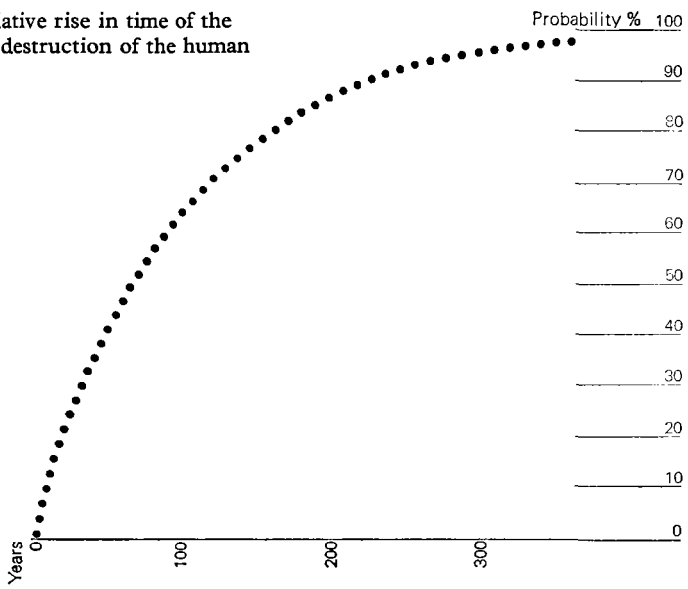


FIG. 1. Cumulative rise in time of the probability of destruction of the human species.

industrialized countries are of the order of 0.02 per cent [1], [2]. This does not provide an estimate of the probability that political leaders would decide on nuclear holocaust, but it is a warning not to underestimate the stochastic weight of utterly rash acts. It suggests, too, that deterrence relying only on the instinct of self-preservation may have limited effectiveness.

Survival of the species

To be sure, limited nuclear conflicts leaving a considerable number of survivors are also conceivable. (The few kilotonnes initially available to new members of the 'nuclear club' do not represent destructive power on a planetary scale.) Yet the threat of total conflict is real and, with cumulative probabilities, the duration of the species might well shrink to the order of another hundred years—negligible in comparison with the average duration of animal species, and short even on the historical scale.

According to one specialist [3], the most long-lived species of mammals alive date from about 3 million years, and the average age of living mammalian species would be about 650,000–1.1 million years. Other experts [4] have calculated the average longevity to vary between 1 and 2 million years. A longer duration is estimated for certain invertebrates: 5–10 million years for molluscs of the cenozoic, 10 million years for bivalves. Although the methods used to study the duration of species has been criticized [5], the figures we cite give a rough idea of the times involved.

The Plio-pleistocenic species of hominidae 'that might have been phyletic ancestors of *Homo sapiens* existed for intervals of at least [750,000 years]. Evidence is accumulating that some survived much longer' [6]. The oldest traces, of *Homo sapiens neanderthalensis*, date from about 80,000 years, while those of *Homo sapiens sapiens* are about 50,000 years old. *Homo sapiens*' origin is controversial, the species having first appeared between 100,000 and 300,000 years ago [7]. If brain development favours the species' longevity, the durability of *Homo sapiens* should exceed that of other hominidae (not to speak of other mammals). *Homo sapiens* would thus be expected to last another half-million or million years.

In 1 million years, 63 per cent of cumulative probability of extinction is reached, using an annual probability rate of 1×10^{-6}; the human species could last so long only on condition that risks of a man-made, planetary cataclysm were drastically reduced. If the high risks persist and if extinction is foreseeable within 100 to several tens of thousands of years, *Homo sapiens* would prove to be an exceptionally short-lived species and its brain development would be dysgenic—detrimental to the species' probability of survival. (Dysgenic is the opposite of eugenic.) In fact, among the late cenozoic mammals, longevities as short as 200,000 years are 'virtually unknown' [6].

Disposing of perilous knowledge

The occurrence of a high-technology conflict at world level is made increasingly probable by a convergence of factors. The tug-of-war for diminishing resources grows stronger while the gap between rich and poor populations widens and may reach limits intolerable to the poor. A tendency towards destructive behaviour is apparent in most industrialized countries as man, in his urban-industrial anthills, feels increasingly 'boxed in' by technological

duress. These factors sharpen the probability of destructive use of our technical capacities, and they may be properly regarded as manifestations of the hypertely we have already mentioned.

Kenneth Boulding has suggested that the present pattern of man's 'noosphere' might prove incompatible with a long survival of the human species [8]. One reason for this may reside in the fact that *anthropos* knows very well how to acquire new knowledge in almost any field, yet he does not know how to rid himself of such knowledge once it has become dangerous or even harmful. The disposal of harmful know-how may prove to be a problem more difficult than that of the disposal of radioactive wastes. Knowledge appears to be, indeed, an indestructible staple. But few things are so alien to many of our minds as the idea of the control of knowledge—thought control or confinement or destruction—since this evokes ideas of obscurantism and repression. So the need for some kind of screening of knowledge is possibly the next challenge to our potential for social evolution.

We concede the hazards inherent in our forecast, but what seems to be much more risky is to fail to consider where the present paths of changing technology might lead. ■

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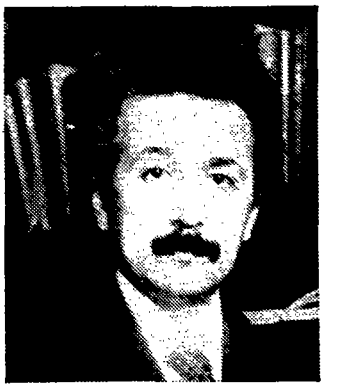

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impact *of science on society*, Vol. 31, No. 1, 1981

During the past forty years, world expenditures on arms and munitions have probably increased fiftyfold. The scientific and technical community has been integrated, part and parcel, in the arms race. The impact of the military-industrial complex on our daily lives has reached enormous proportions, but there are ways of reducing appreciably this diversion of socio-economic resources.

Influence of weapon development on scientific research

Ignacy Malecki

A physicist and specialist in the science of science, Professor Malecki is a member of the Praesidium of the Polish Academy of Sciences and director of Poland's Institute of Fundamental Technological Research. He previously headed Unesco's Department of Science Policy and Promotion of Basic Sciences. He is currently a member of this journal's editorial advisory board, and a contributor to our recent issue on research and social goals (Vol. 29, No. 3, 1979). Address: ul. Asfaltawa 11, m. 12, 02–527 Warszawa, Poland; telephone 49 11 43.

Quantitatively speaking

The development of scientific research designed to meet armament needs should be considered against a background of growth of the world's militarization. Here two figures are most important: total expenditures for arms and their rate of growth.

United Nations data indicate that money spent on arms in 1980 was of the order of $410,000 million. This means that, each minute, the world spends $1 million to purchase arms. At constant prices, spending on arms since the Second World War has increased fourfold. Since 1939, such spending has probably increased fifty times—although uncomparable prices make accurate estimates difficult. But current spending on armaments absorbs annually 6 per cent of all the world's gross national product (GNP).[1]

During the mid-1970s, 75 per cent of all money spent on armaments came from the highly industrialized countries. During the same period, it is unfortunate to note that the developing countries had a higher rate of growth in arms acquisition than the average for the world. Between 1960 and 1972, the developing nations raised their rate of growth in armaments by a factor of 4.2, while the increase in their GNP did not exceed 2.7 per cent by the most optimistic estimates. Countries such as Egypt, Israel and Saudi Arabia, which in 1970 had trailed far behind arms-developing industrialized economies,[2] now belong among the first ten countries maintaining a large military potential.

It should be added that the expenditures made on arms by developing countries are three times as high as the external assistance they obtain. It can be concluded that arms for these nations are procured at the expense of the most vital needs of their populations. It is to be admitted that figures such as these and those cited above are only estimates because many countries publish no data on their military spending, and much of the budgets allocated to non-military items is used indirectly to increase the armamentarium. Nevertheless, the overall estimates of expenditures on weapons and their general trends are clear and open to little doubt.

Some comparative elements

More difficult to estimate are the expenditures consecrated to research and development on armaments. This is attributable to the following factors: (a) many research projects, such as those conducted at universities, can be used for military purposes but without direct funding by the military; (b) the same applies to aerospace and nuclear energy research, which, in the case of the United States, amounted in 1970 to 60 per cent of the military R&D budget.[3] No comparable figure is available for the Soviet Union; (c) military R&D expenditures are, for many reasons, not normally treated in global military budgets in the process of parliamentary approval; (d) the boundary between (i) research and development and (ii) production is mobile and thus difficult to establish firmly; (e) the contribution of industrial corporations to military R&D is important but cannot be exactly evaluated. So it is necessary to refer to estimates developed on the basis of comparative analysis.

Sivard[4] claims that in 1975 the world spent $25,000 million on military R&D, signifying an increase of the order of 30 per cent during the half-decade between 1970 and 1975. A general appraisal of the percentage

of R&D within the total military budget is slightly less than 10 per cent, but this percentage tends to grow for reasons which are discussed below.

Distribution of the financial means available for military R&D is different, among diverse nations, from that of the total credits for arms. The highly industrialized powers represent about 85 per cent[5] of the world's potential in military R&D, a fact determining the very character of the research and development undertaken. A few developing states (Brazil and India, for example) are building their own military R&D potential, although the full industrial integration of this potential will probably not occur before the mid-1980s. China and South Africa do extensive work in research on nuclear energy, research which is intended to lead to the production of nuclear weapons.

How many really work in military research?

Apart from expenditures, an important evaluation factor is the number of employees engaged in R&D projects designed to meet military needs. It is plainly difficult to make accurate assessments on this score, but as a point of reference we can cite figures given by E. H. Burhop, president of the World Federation of Scientific Workers, in his address to the Tenth Special Session of the United Nations General Assembly in 1978.[6] Burhop said: 'Approximately 10 per cent of the world's industry is orientated towards armaments.' He noted that about 20 per cent of all highly skilled workers are employed in military production, 'while for highly qualified scientific and engineering staff this index is as high as 40 per cent'.

It is possible to derive another figure by taking $1 million as the annual cost of an R&D project employing approximately twenty qualified scientists and engineers. On the basis of comparable sampling analysis applied worldwide, it can be concluded that the figure offered by Burhop is rather high—the figure of 30 per cent seems to be more accurate.

Taking into account that roughly 2.5 million scientifically trained people (not counting specialists in the human and other social sciences) are working in research and development, one can then appraise that about 850,000 specialists work directly or indirectly in the field of military R&D.

Science's role in the world of armaments

It is obvious that feedback exists in the relationship between scientific progress and advances in armaments. Some specialists claim that the arms race resulting from technical innovation, innovation based on advancing scientific technology, is a process of fatalistic character. 'Military technology is an area in which notions of inevitable continuity are particularly prevalent, that has a life of its own; it is an area in which man has lost control of his social structures.'[7]

In a report of experts presented before the United Nations General Assembly of 1971, we read, 'This technological arms race . . . is carried forward to some extent under its own impetus. It is open-ended; in the absence of political action, there is nothing to stop it going on

indefinitely.'[8] Another specialist, D. Senghaus, voices a similar opinion.[9]

The thesis seems to be too far-reaching, however, because both science and the concept of technical innovation alone create the possibilities for new military technology. The use of the latter depends, first of all, on political and economic factors. The economic element is njected because competition in the development of armaments is also competition on the world's arms market. In some of the most industrialized economies, proceeds from the export of arms can refund 30 per cent and more of the cost of arms production.

There is no reason to believe that science, generally speaking, is a fatalistic driving force in the arms race. Yet it should be realized that the role of science in the sphere of the development and production of armaments is more important than in other spheres. There are several reasons for this, so let us examine them.

Mini-analysis of the role science plays

First, modern weapons are based on the exploitation of far more numerous physical phenomena than was the case during the Second World War. We mention only the most important of these phenomena:
Use of the effects of nuclear fission and fusion.
Launching and controlling the actions of objects released in nearby outer space.
Semiconductors and the development of technology in micro-electronics.
Coherent light beams (lasers) and their many technological applications.
Geophysical phenomena and the growing possibilities for using these to cause disturbances in the environmental equilibrium.
All these effects or processes have thus far been investigated only partially. They offer to science some very promising prospects indeed.

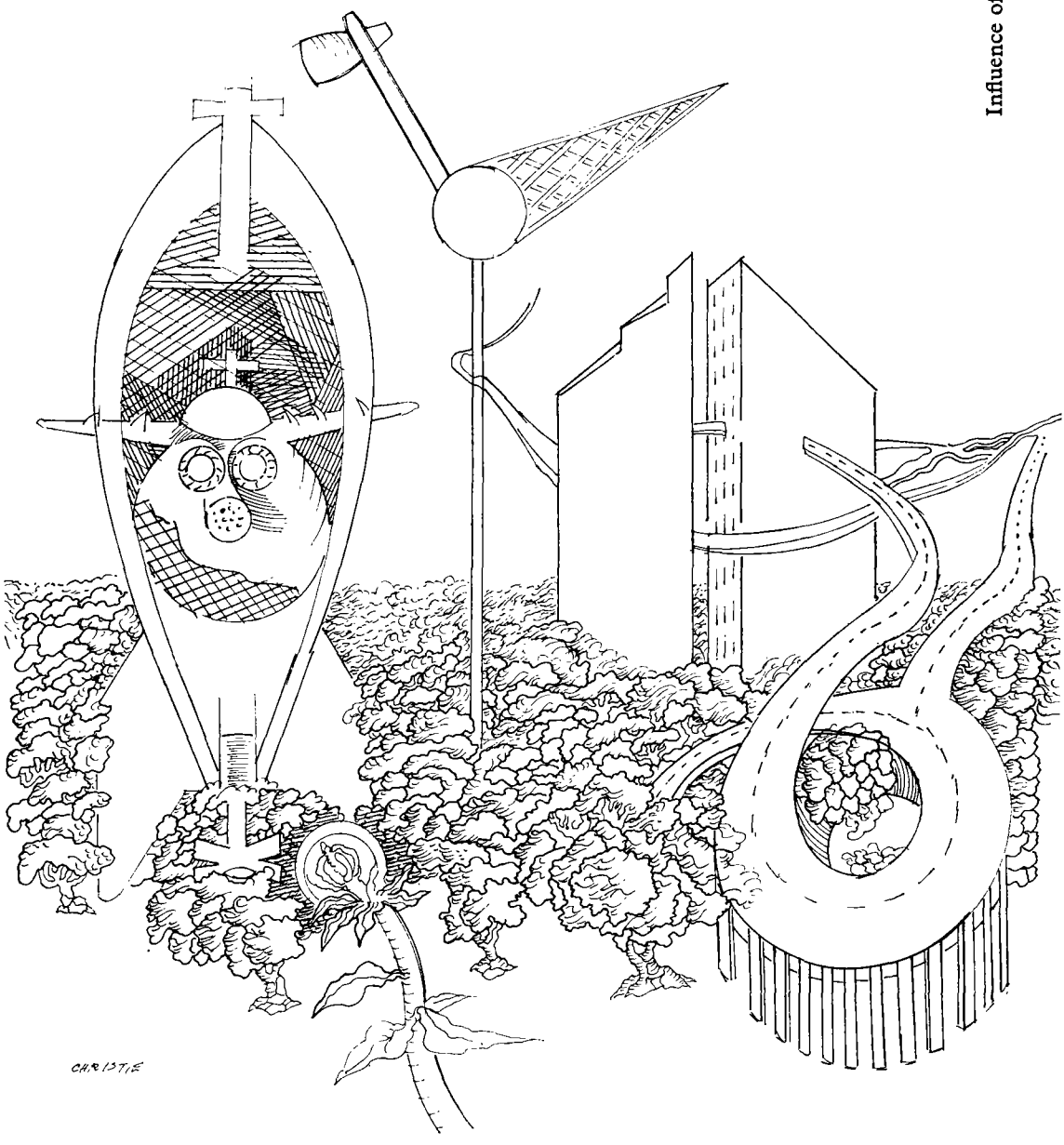
Secondly, events in recent years have shown that, in the arms race, quantitative superiority in technologically equivalent weapons is not as important as the deployment of qualitatively new weapon systems. So it is evident how important the role of scientists is in developing new weapons: it is of primary significance. A state attains a better strategic position as a function of the new weapons that can be produced in the near future on an industrial scale.

Thirdly, research is more concentrated than arms stocks in certain parts of the world. Weapons proliferate from the most industrialized countries by way of export—accounting for probably 60 per cent of all military hardware ready or semi-ready for use. This is of vital significance to the relationship of research projects with armament policy. It is a matter of fact that the country importing the most modern military material becomes increasingly dependent on the supplying country, one which permanently introduces technical innovations derived from its research centres. We know from a United Nations report[10] that the research and other scientific potential of the six most powerful nations engages ten times more material resources and manpower than in all the other countries. This figure tells a tale requiring no further comments.

Military R&D and socio-economic progress

A typical view of this problem is that expressed by two experts on the problem, Booss and Rasmussen: 'The contribution of military research to science as a whole has been relatively small and often rather worthless as compared with the intellectually more challenging and more creative problems of civil branches.'[11] It is necessary here to make a distinction between the contribution of military research to the general store of human knowledge and its influence on the development of the civil branches of human enterprise, mainly industry. The statement by Booss and Rasmussen seems valid because the contribution of military research to the general development of science is minor when one appreciates the means involved.

This state of affairs derives mainly from the hiding of most of the results of military scientific investigation, results that cannot be published and made available to the rest of the world of science. There is another factor,



too, one consisting of a very narrow approach to given scientific problems—problems seen only from the point of view of the requirements of military technology.

As to the advance of military R&D and its influence on non-military technology, this influence is often overestimated, especially by military circles in the United States. The term 'spin-off' was coined to convey the proliferation in civil industry from the achievements of the arms industry. It is estimated, however, that in the most favourable of circumstances, not more than 20 per cent of military-orientated scientific research will have applications for civil technology. This follows, indeed, from the fact that current military technology is so highly specialized that it shares little in common with civil technology. Military R&D fixes as goals—speedy supersonic aircraft or the superminiaturized packaging of components within a given device are fair examples—certain objectives that are not so important in civil application.

Attaining the military goals means, in other words, that science and technology must solve completely new problems. Research in material science and in optical electronics, for example, demands a huge scientific effort funded by ample financial means; its results have little use in civil technology. One of the few examples of the direct application of military technology to civil life is that of the jet-engine aircraft.

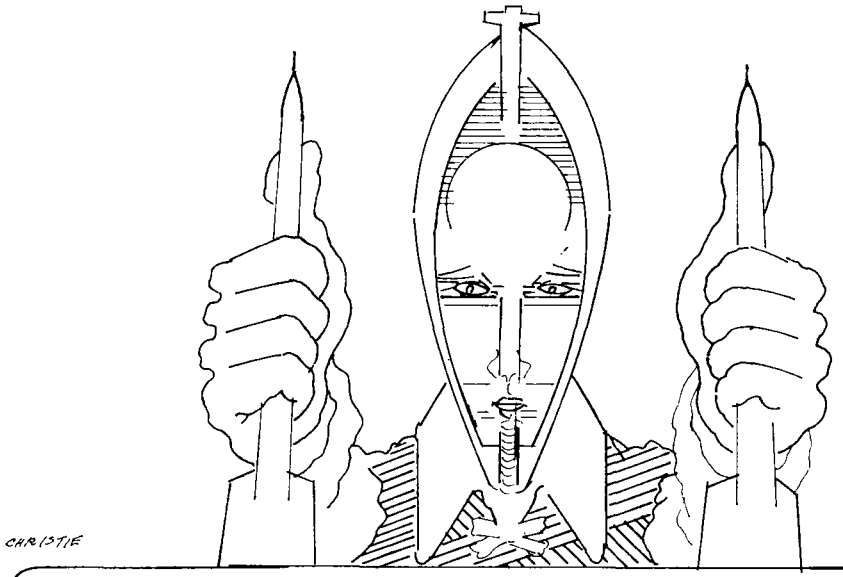
Yet another question to be asked in certain countries is how the civil population can most profitably use military-orientated facilities such as some highways and certain railways. Their level of utility may be low because the civil population's mobility is not compatible with the presumed need to shift military units with considerable speed.

Technical innovation without resistance

It is also necessary to take into account that military research engages both specialists and the financial means that would otherwise be employed in civil research and would contribute so much more to the development of knowledge and the socio-economic progress of nations. It is here that the current clear preference for military R&D is harmful to both general scientific progress and the ascent of man. We have seen that the preference results from political decisions as well as some important economic motives. It is paradoxical, however, that the advancement of military technology is independent—to a large extent—of the current economic situation and sometimes even disregards economic difficulties. The usual supporting (but very doubtful) argument is that a rise in arms production lifts the economy while reducing unemployment.

There is another factor which is favourable to technical progress in armaments; this is the relatively short time between the realization of an innovation and its introduction in mass production. Civil industry encounters many constraints (determining users' habits, costs of introducing a new product on the market, lack of co-ordination within the commercial distribution system), whereas military organizations bring about technical innovation almost without resistance (mainly because the costs of renewing hardware are already part of the defence budget).

These factors combine, also, to raise the efficiency of the brain drain in some countries: military research institutions siphon specialists away from the civil sector of the domestic economy. The relatively small spin-off from



military research, already alluded to, is not even uniform throughout the myriad activities undertaken in the name of defence R&D, implying further waste of resources. I concede, however, that in some domains military goals have inspired certain basic research. Nuclear research is an illustrative example.

Science against the arms race

Although the significance of science in the arms race is by now well recognized, its role in promoting international détente, the relaxation of tensions, is sometimes underestimated. It is possible here to distinguish three ways for science to have influence. First there is the activity of scientists themselves; it is not by accident that these have made important contributions to peace movements, to wit, the Pugwash Conferences on Science and World Affairs. The importance of the attitude and opinions of researchers is based on several considerations: (a) scientists enjoy positions of high authority in contemporary society, and their voices are taken into account by public opinion; (b) they have an adequate background to estimate, comprehensively and objectively, the possible consequences of the arms race and armed conflict; (c) the scientific community being a contributor to innovations in weapons, its individuals feel responsible to some extent for the course of events; and (d) scientists can use, as no other group can, their wide international contacts to help ease political tensions.

Another role falling to science and scientists is that of helping relax the tensions caused by uneven socio-economic development in the different regions of the world. Here we think of science's contributions to research orientated towards meeting basic human needs such as food, good health, adequate shelter and energy supplies. It is true that progress in fulfilling these requirements depends mainly on political and economic reasons, but science is capable of opening new doors in the solution of the most urgent problems. Prime examples of such door-opening are the recent 'green revolution', the elimination of contagious diseases like smallpox, and the development of new and renewable energy sources (e.g. *gobar* gas in India and elsewhere in Asia, '*gasohol*' in Brazil and other countries).

The third sphere of science's influence concerns culture and ideology —fields lying within the province of the human sciences. Through these social sciences, it is possible to structure the overall 'political atmosphere' by the provision of factual material for distribution through the mass media, to improve textbooks and other teaching materials, and the like. The objective presentation of historical, current political, economic and other cultural events eliminates distortions which can exacerbate antagonisms between and within population groups.

We have reviewed some of the problems which are, in our opinion, critical in the relationship between science and feats of arms. The entire issue is so complex, so vital to the continued existence of contemporary society, that it cannot be evaluated or judged hastily on the basis of generalized conclusions. ■

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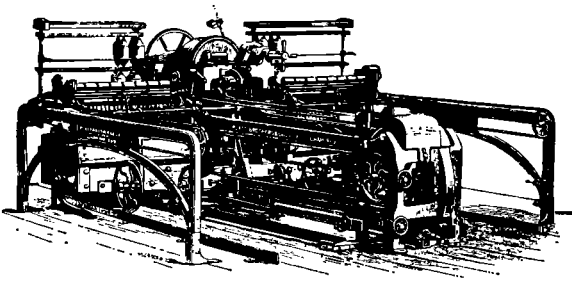

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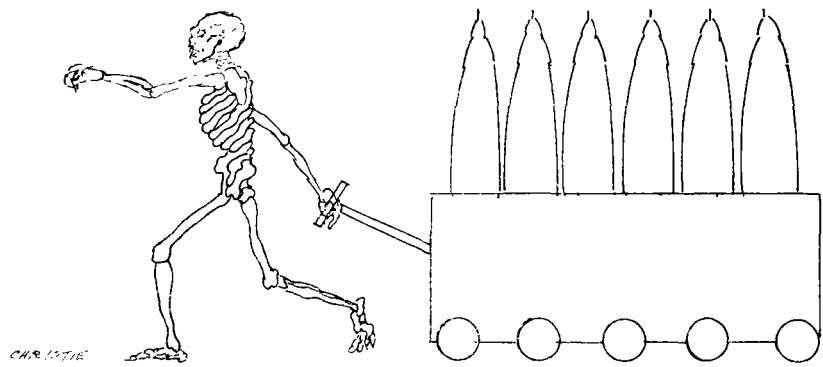
Military research and development seem to have become permanent fixtures of some societies, deforming the purposes and possibilities of the civil scientific endeavour. It is not too late, however, to change these habits and redirect our research pursuits to the satisfaction of both human needs and intellectual curiosity.

impact *of science on society*, Vol. 31, No. 1, 1981

Significance of military R&D

The impact of the arms race on society

Marek Thee



The author is senior research fellow at the International Peace Research Institute, Oslo, and editor of the quarterly journal, Bulletin of Peace Proposals. *Dr Thee edited* Armaments and Disarmament in the Nuclear Age *(Stockholm International Peace Research Institute, 1976; also available in Finnish, French, German, Norwegian and Serbo-Croatian) and* Problems of Contemporary Militarism *(London, Croom Helm, 1980). Address: Institutt for Fredsforskning, Rådhusgt. 4, Oslo 1, Norway.*

The rising power of military science

No single sphere of human activity exerts a greater impact on contemporary society than military research and development (R&D). Military research does this in two ways: on the one hand, by serving both as pace-setter and accelerator of the arms race, and, on the other, by perverting values and distorting priorities in science. As never before in history, modern science has a pervasive effect on mankind. Indeed, it raises the question of the continued existence of the human species. The fact that military R&D has gained a commanding position in science and technology must, in these circumstances, be of great concern to us all.

None other than former American President Dwight D. Eisenhower, a great soldier and statesman, warned of possible 'grave implications' stemming from the 'rising power of military science'. He pointed to the 'danger that public policy could itself become the captive of a scientific-technological élite'. Eisenhower feared the mushrooming growth of military R&D which, 'in conjunction with an immense military establishment and a large arms industry', exerts enormous 'economic, political, even spiritual' influence. Humanity—we can only repeat Eisenhower's words—'must guard against the acquisition of [this] unwarranted influence'. It should be emphasized that Eisenhower's concern was not about basic academic research. Rather, he was talking about 'the rising power of military science', the role of which is increasing in step with the escalation of the arms race.[1]

It is a well-established historical law that there exists an intimate structural relationship between military technology, state power, institutions of government and—indeed—the socio-political environment of nations. Naturally, this positive correlation chain of cause-and-effect is much stronger today, at a time of an explosion of military technology. Science-based arms have profoundly changed the nature of war. They have undermined security, making all states, big and small, vulnerable to new technology-intensive weapons; and they have alienated society from comprehension of the dynamics of armaments. Consequently, security fears are much more easily manipulated today than in the past, and this tends to make society hostage to the arms race. The arms race has acquired a momentum of its own, in fact, above and beyond social and political control. But it may be difficult to assess and grasp this in-built momentum of weapons and its societal effect without first taking into account the function and character of contemporary technology and military R&D in particular.

The dimensions of military R&D

The true role of military R&D in relation to the arms race can best be seen in the growing importance attached to it, in both East and West, in view of the recent upsurge in spending on armaments. This is reflected in the boost which military R&D received in the 1981 military budget of the United States. While the real increase in defence outlays over the 1980 budget is slightly over 3 per cent, the budget for military R&D—including programmes approved for production—provides for a jump of over 22 per cent: 'to strengthen our technological base, significantly upgrade our strategic capability, and modernize our conventional forces', in President Carter's words.[2] In the period following the Second World War, the growth rate of military R&D on a global scale has exceeded the increases in armaments expenditures by an average factor of four to five.

Because the USSR, China, and the East European countries do not publish detailed accounts about the burden of their military effort—not to speak about the dimensions of military R&D, computations of world investments in military R&D in human and material resources have to be made on the basis of information made available by the Western powers.[3]

Considering the Soviet output of modern weapons and its drive to equal and surpass Western levels, one can safely assume that in the East the focus on military R&D does not lag behind the standards of the West. Since the West is ahead in modern technology and general technological efficiency, one could even expect the Soviet Union and its allies to invest more intellectual and material resources in military R&D than the West in an attempt to match the latter. A recent indicator of this effort is the steep increase in the training of engineers in the Soviet Union, each year's graduates in this field now approaching 250,000. Most of these are in branches related to military R&D.

According to conservative estimates, about half a million of the best qualified physical and engineering scientists in the East and the West are today employed in military R&D. Assuming that on the average 10–15 per cent of world military expenditure (now approximately $500,000 million annually) is devoted to military R&D—figures which accord with Western data[4]—we may compute that, on a global scale, military R&D currently absorbs some $50–75,000 million yearly. This is certainly so if we add space research and basic research, the lion's share of which is intrinsically linked to military R&D. It follows that one-third to half of the world's resources allocated to R&D (estimated at $150,000 million annually) is devoted to military purposes: more than the cumulative R&D investments in energy, health, information processing, transport, pollution control, and agriculture.[5]

Big is beautiful?

Special attention to military R&D evidently has dramatic effects on both the arms race and the very fabric of society. This research reflects a double distortion, that of priorities and the maldistribution of resources; there is the central role of military R&D in the global scientific and technological endeavour, on the one hand, and there is also the relatively low rank of research devoted to human needs and development, on the other. These issues are functionally interrelated. The huge proportion of resources appropriated to military R&D leaves littles funds for research focused on bettering the human condition, and the high priority accorded to military affairs lowers the rank accorded to civil R&D.

Most military R&D is concentrated in countries producing the bulk of advanced weapons: the superpowers, particularly the United States and the Soviet Union, which control approximately four-fifths of the global effort in military technology. This is part of the dominance-dependence relationship in world affairs; it reflects both the paramount international position of the largest powers, and the dependence of all other countries that have to acquire weapons as well as civil and military technological know-how from these powers. By corollary, and largely resulting from the world's military order and power hierarchy, comes the blatant disproportion in the distribution of R&D capacity between developed and developing countries.

Statistics for 1973 show that, on a global scale, funds spent for R&D were controlled to 97.1 per cent by developed countries and to 2.9 per cent by

developing nations, while 87.4 per cent of scientists and engineers working in R&D were living in developed countries, and 12.6 per cent in developing countries.[6] The conduct of massive and intense R&D and the maintenance of well-equipped laboratories have become highly costly. Only the big and the rich can afford to compete effectively. In these circumstances, the abundant funds at the disposal of military R&D help to assure predominance in research within non-military domains. Geared as it is to the needs of the military, then, R&D overlooks many of the requirements of development of the civilian economy, neglecting particularly urgent needs in developing countries.

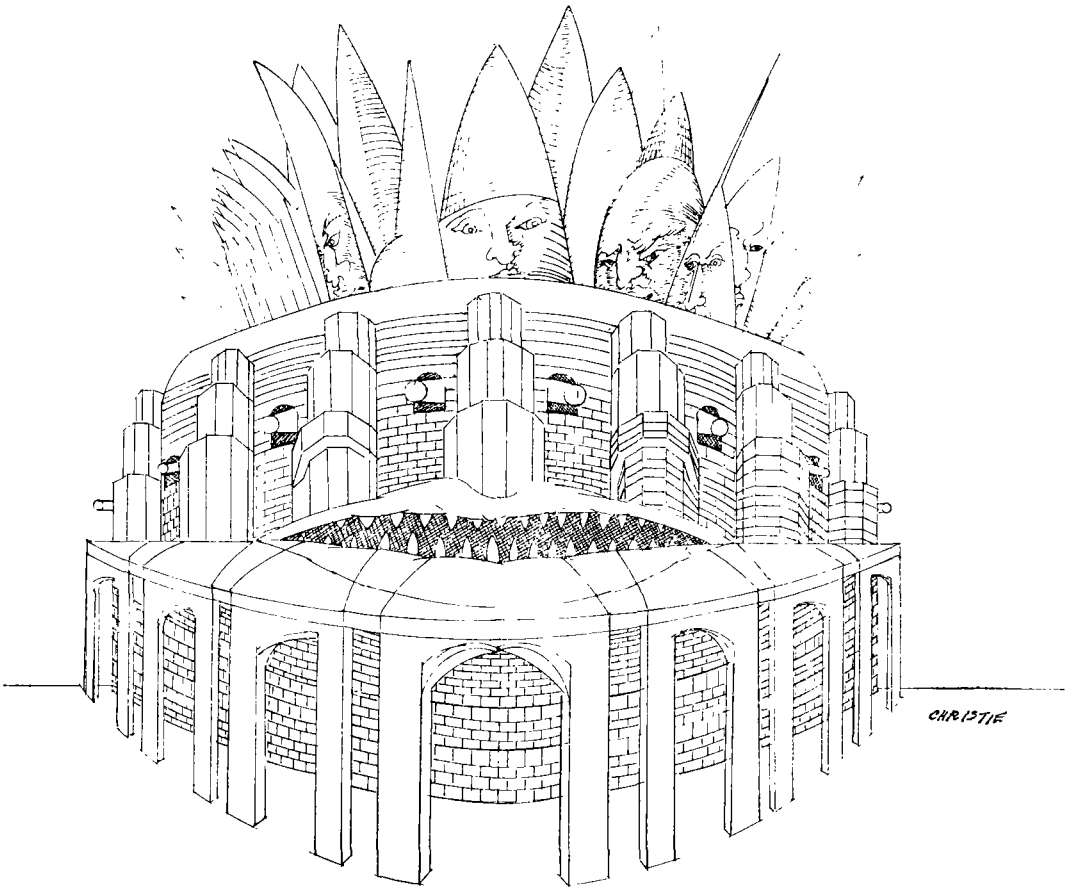
The dynamic element

The skewed distribution of resources and their quantitative computations, however, do not tell the whole story. More important is the qualitative aspect, the institutional set-up and mode of operation of military R&D. These regulate the intrinsic dynamics of the arms race and contribute to the growing power of military science in society. Five major structural factors can be distinguished in the dynamics involved.

First, the impact of the competitive drive within the mammoth empire of military R&D. This adds vitality and serves as an energizer of the arms race on the one hand, and acts to assert the dominant influence of military R&D in civil branches of the research enterprise, on the other. In recent decades, science-based military R&D has expanded both horizontally and vertically—into thousands of laboratories, university research centres and industrial firms as well as into most disciplines of science. These include not only the most advanced natural and engineering sciences (nuclear energy, electronics and microelectronics, high-energy physics, aerodynamics, space technology, computer technics, telecommunication, physical and advanced polymer chemistry), but also the human behavioural and medical sciences (biology and biochemistry, sociology and psychology, economics and management). It has come to encompass technology across the entire spectrum of modern warfare—from intelligence and communication through automated battlefields and the penetration of all land, sea, air, and outer space, to psychological warfare and 'brain-washing'. No sphere of advanced science remains outside the interest of military research. The command of vast areas of modern science and technology has had a multiplier effect of immense importance for the military. The most exotic weapons of science-fiction such as 'direct energy transfer' arms (or death-rays), based on charged particle beams and high-energy lasers, have now become the subject of intense research in East and West.*

By definition science-and-technology-intensive modern armaments thus derive from almost all domains of advanced sciences; they monopolize a

* In 1980, the Union of Soviet Socialist Republics and the United States of America spent an estimated $400 million to develop a new category of arms—energy-beam devices. The high-energy laser is intended to kill by means of the heat of a narrowly focused and highly intense beam of light, whereas charged-particle beam weapons are meant to use streams of electrons or protons to produce 'lightning' bolts. The latter weapon does not seem to be practical, but it is unfortunate that the same cannot be said of the former.—Ed.



sizeable part of research funds available. They exert a decisive influence on the nature and the very direction of contemporary scientific and technological endeavour. This disarrangement of priorities, extrapolated into the future, could well have a disastrous effect on human development.

In this context, special attention should be given to the compulsion for technological competition in armaments which fuels the arms race. Its propulsive effect is felt on both national and international levels. On the national level, the race is invigorated by competition between various research centres (governmental and private) as well as by institutional rivalries between the branches of the armed forces (land, air and sea), competing to acquire the most advanced weapons. On the international plane, the quest for new military technology is expressed in cycles of moves and countermoves, parallel to the action–reaction dynamics feeding the arms race. Internal and external pressures intermingle to reinforce, exponentially, the momentum of the arms marathon. While the action–reaction dynamics is well known, less attention has been given to the artistic, self-sustained, and inner-directed impulses. These reflect not only material driving forces (the reward system and financial opportunities), but also such factors as ambition, attitudinal postures, and the scholarly urge. In reality, a large part of the technological competition is directed against one's own achievement: reaching for greater excellence, taking into account anticipated technological advances at home and abroad, even planning for science-fiction scenarios. One's current armoury is thought to be obsolete, and the future thereupon becomes history.

Second, the effect of the long lead-times required to develop new weapon systems and introducing them into the armamentarium. The 'gestation' has to go through shorter or longer stages of initial concept and design, research, development, testing, production, renewed testing, evaluation, acquisition, and finally deployment. On the average it takes ten years to produce a new weapon system. Such a long gestation assures constancy and continuity within the armaments process. Once begun and once the initial decision and investment have been made, projects have to be maintained for years. The nature and structure of the R&D exercise combine with governmental bureaucratic inertia to strengthen commitments in the planning of weapon systems. Moreover, long lead-times serve as a catalyst for early decisions about new weapon systems; the logic here is that of renewing one's own armoury, and thus to pre-empt the adversary. So the quest for new arms becomes a permanent activity, proceeding independently of drifts in politics, governmental change, or arms control and disarmament negotiations. Arms control negotiations are, as a rule, about weapons which in military R&D considerations are in fact thought to be obsolescent. In the meantime, new weapon systems are produced in secrecy by military R&D, systems which tend to make arms control agreement obsolete. This state of affairs cannot but have a devastating effect on efforts to control arms and stimulate disarmament.

Third, the so-called follow-on imperative and growth propensity of military R&D, inherent in the technological drive. It is a known socio-political law (already mentioned) that any bureaucratic structure or institution of size tends to expand spontaneously. Once a permanent infrastructure has been laid, the conditions for germination of this growth are present. But in the case of military R&D, objective conditions turn into obligation. Military R&D can be made functional only if pursued with purpose, without interruption, and with a vision of moving with time and climbing the ladder of innovation—keeping pace with the technological revolution. The completion of one weapon system requires follow-on by a new system at a higher level of technology; the development of offensive arms has to be followed, or even paralleled, by the initiation of defensive systems, and vice versa. Laboratories cannot stand idle; skilled manpower must be maintained; increasingly more complex weapon technologies require new talent, new recruitment, new investments. All this feeds the arms race; and the stronger the technological momentum, the greater the need to rely on more elaborate military R&D. Expansion is part of the very nature of military R&D: the 'rising power of military science', about which Eisenhower was so concerned, is ever with us. It is a dynamic process sending its roots deeper and deeper, encroaching on the structure of modern society. It corrupts science, weakening instead of strengthening our defensive power.

Fourth, much of the strength and innovative capability of military R&D lie in the block-building and cross-fertilizing effect by which projects, initially unrelated but complementary in their technologies, meet to accomplish breakthroughs and produce entirely new weapon systems. This was the case, for instance, with the development of the strategic reconnaissance satellite programmes and the multiple independently targetable re-entry vehicles (MIRV).[7] By their very abundance, weapon development projects converge to produce building-blocks for altogether new military technologies.

This effect depends largely on the openness of technological research

Military R&D, conducted in a closed environment, cannot fully take advantage of this cross-fertilizing potential. Interesting to note is the considered opinion of the scholarly community that part of the Western superiority in military technology stems from the relatively greater openness of research in the West. As dialectics would suggest, full openness in technological research might have a far more beneficial effect. It would draw wide attention to the tremendous potentialities inherent in this activity, not for destruction but for constructive purposes. In fact, rational socio-political reasoning would insist not upon the dismantling of military R&D but upon its conversion to non-military human needs. The cross-fertilizing effect, in complete openness, could then be used to its full extent.

Fifth, structurally related to the rising power of military science is the mighty socio-political constituency of military R&D: what Eisenhower termed the military-industrial complex,[8] but what has grown since to become a much broader competitive alliance of the military, the military industries, large parts of the state's political bureaucracy, and the civil technological establishment linked to military R&D. There is competition and compatibility of interests in this alliance—competition for political prevalence, for military orders, for the selection of weapons and choice of doctrinal command. But, overriding the competitive currents is the common striving for military strength. Military R&D is one of the most important and sensitive links in this chain of relationships; it is the sinews of power. In a sense, there is an interlinkage of interests in this military-manufacturing-bureaucratic-technological complex, with military R&D (more than in the case of the other partners in the alliance) having almost unconditional support from all sides. Military R&D in conjunction with its military-industrial-bureaucratic constituencies form what Eisenhower called 'the web of special interest' enjoying 'an almost overpowering influence' in state and government.[9]

In different forms and institutional set-ups, this web of special interest exists in both East and West. It is to be found everywhere: (a) where the military services 'traditionally concerned with 100 per cent security, are rarely satisfied with the amounts allocated to them';[10] (b) where the military industry, in private or governmental hands, is in pursuit of always larger orders and of expansion; (c) where the state's bureaucracy is vitally interested in using military power as an instrument of policy and diplomacy; (d) where the scientific-technological establishment employed in military R&D sees its fulfilment in the prosperity of their laboratories and almost unlimited technological experimentation.

Thus, military R&D cannot be apprehended and analysed in static terms. It is one of the most dynamic institutions of our time, acting with resolution and aggressiveness. It has the advantage of being in a position to manipulate natural forces which frighten large segments of society. It is one of the main engines behind the arms race, and one of the least researched and least manageable offspring of military technology.

Values, priorities and social control

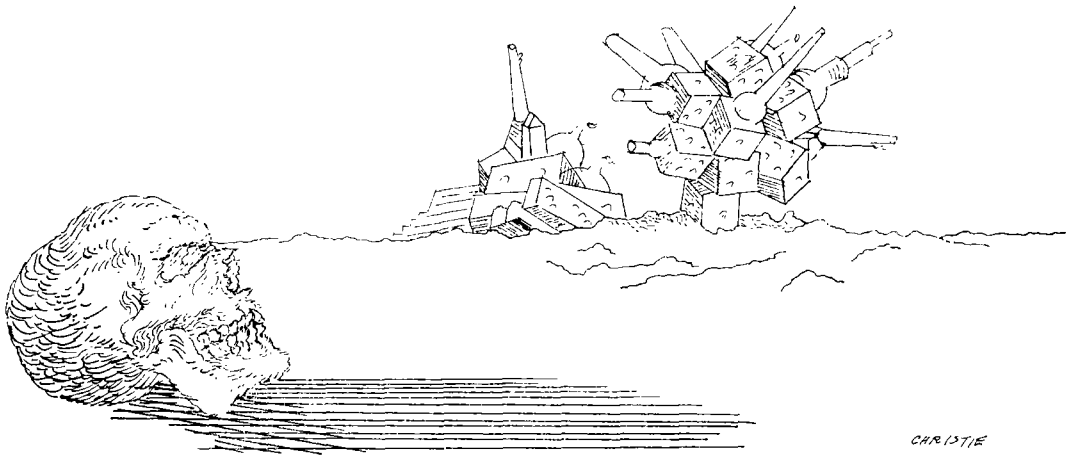
We need therefore to learn more about military R&D, its functioning, the objects of its research and the role it plays in society. Though science and technology are critical for human development, and military R&D is

increasing its influence on the scientific-technological endeavour, our knowledge of this empire is strikingly sparse. We need more research, action-orientated research, to make military R&D more transparent, to help to change priorities in all R&D, to further disarmament efforts and introduce an element of social control into the activities of military R&D.

A strange and dangerous situation has developed. Day by day the arms race is being intensified while, at the same time, there is apathy in the struggle for disarmament. We have become (a) estranged from the race in military technology and (b) 'socialized' to escalating armaments. Indeed, the faster the race, the lower seems to be our awareness of the perils ahead. This process has been stimulated by various official whispers which try to spread the theorem that the race in military technology is too complex to be understood by the general public; hence, it has to be left to the experts. The race then continues unhampered.

Yet military R&D is related not only to questions of peace and war. It also has to do with a general malfunction of society. Military R&D's impact is social, economic, political and cultural; and these problems are interrelated. Involved is not only 'a distorted use of the nation's resources', but (as Eisenhower added) there is a danger for 'our liberties' and the 'democratic processes'.[11] Basic human values such as peace, security, freedom of research and speaking out against its misuse, and the right to democratic participation in shaping research—all these are at stake. Somehow, the momentum of military technology and the military imperative seem to act more strongly than human rationality and our attachment to basic values and norms.

Humanity has always been confronted with the dilemma of science and technology having dual edges, one for good and one for evil. We are well aware of the great contribution of science and technology to the advancement of humanity and its well-being. We seem to have arrived, however, at a new crossroads. The development of means of destruction for military purposes is perverting the scientific endeavour, probably with unpredictable consequences. As stated in the Final Declaration of the 1978 Special Session of the United Nations General Assembly devoted to disarmament: 'The competition for qualitative refinement of weapons of all kinds, to which scientific research and technological advances are diverted, pose incalculable threats to peace.' So is the danger for human integrity and our civilizational



and cultural legacy. It is time to halt and reflect. Humanity needs moral judgement better to instruct our behaviour and make science more human and wise.

Spin-off and other rationale

There are those who point to a number of spin-off benefits for civilian technology coming from military R&D, as in the fields of nuclear energy, communication and electronics. But investigation of these spill-over effects has shown that they are negligible in comparison with the overall investment in military R&D.[12] It would be strange, indeed, if no tangible spin-off were forthcoming from such a vast scientific-technological activity. Simple logic and cost-effectiveness computation show, instead, that if the tremendous resources wasted on military R&D could be channelled into peaceful applications, the accrued benefit to humanity would be equivalent to thousands of spin-offs from military technology.

There are others who would defend military R&D on national-patriotic grounds, invoking the traditional freedom reserved for scientific research, or else the value-free approach to science. These may be valid arguments in certain circumstances, but they tend today to lose their validity. More than other groups in society, scientists serving military R&D should be aware that the race in military technology and the accumulation of increasingly sophisticated weapons have not increased security; these efforts have made the world more insecure than ever. Ingenuity is now needed, not for increasing the stockpiles of arms but to halt the absurd race. Once equipped with better insight into the likely consequences of modern warfare, scientists cannot dissociate themselves from the use made of their toil. They cannot divorce themselves from the social and moral responsibilities inherent in their work.

The nature of research and the position of scientists and engineers have changed to such an extent that these specialists have lost much of their once cherished independence and autonomy of action. Science and technology have become mass professions, institutionalized and regimented, largely subordinated to a managerial bureaucracy. The original values of science—the search for knowledge, truth and human betterment—require an active stand against both the constraints of bureaucratic management and the corruption of science by military R&D.

Specific action is possible

Two ways are open to deal with the current situation. The first involves an educational effort to sensitize, to generate awareness about the predicaments caused by military R&D, the arms race, and distortion of priorities in R&D. The second approach is an effort to introduce social control into R&D, to bring to a halt the dynamics of military R&D, and to change priorities with the ultimate goal of converting the bulk of military R&D to peaceful purposes.[13]

These are not easy tasks. Existing structures in military R&D are sustained, as we have seen by powerful vested interests, and there is a regrettable lack of understanding within governments and the public for an urgent need for change. It is in this vein that Final Declaration of the 1978 Special Session of the United Nations General Assembly on Disarmament stressed. 'It is

essential that not only Governments but also the peoples of the world recognize and understand the dangers of the present situation.' Any strategy of change, then, must be based on long-term planning.

Within this strategy, a central role must be reserved to concerned scientists. The aim here should be to activate as large as possible a part of the scientific community in the cause of change. A useful tool in this respect can be found in Unesco's Recommendation, on the Status of Scientific Researchers, adopted by the Organization's General Conference in November 1974.[14] It postulates, *inter alia*:

Openness, autonomy, and freedom of research.

Incorporation into educational curricula of materials fostering intellectual integrity and a spirit of civic and ethical responsibility.

The right and responsibility freely to pursue, expound and defend scientific truth.

The right to participate in the definition of aims and objectives as well as in the determination of methods of scientific research.

The right to participate in the outlining of national scientific research and experimental development policies.

The right and responsibility to express oneself freely on the human, social, or ecological value of certain projects.

The right and responsibility to withdraw from projects that run against the scientist's conscience.

Freedom to publish and speak out.

Freedom to share knowledge with the public and engage in informed public debate.

Freedom of international interplay of ideas and information, including material support for international contact, communication and travel.

Freedom of professional association to protect and promote the individual and collective interests of scientists.

This is an impressive list—indeed, it could be seen as an outline for a code of conduct and rights of all scientists combining a value orientation with the activation of social and moral responsibility. Its main thrust is the quest for autonomy for the scientific researcher, freedom from manipulation, and reassertion of independence. It should bolster civic posture as well as social and moral responsibility.

Exercising control and restraint

There is also an urgent need for immediate efforts to introduce restraint and control of military R&D. In this respect, the Final Declaration of the Tenth Special Session of the United Nations General Assembly called for 'negotiations on the limitation and cessation of the qualitative improvement of armaments, especially of weapons of mass destruction, and the development of new means of warfare so that ultimately scientific and technological achievements may be used for peaceful purposes'.

This is a tall order. But there are concrete steps that can be taken immediately to limit the momentum of military R&D effectively. Two of them are long overdue. One is a comprehensive nuclear test ban treaty; another is a ban on the testing of new missile delivery systems. These are both highly feasible. They can be controlled and verified with 'national means' of control. They would impede the process of weapon development at one of its most sensitive stages: the testing of key strategic weapons. A halt to

testing could give us a badly needed respite, one that could inject new life in today's stalemated arms control/disarmament negotiations. It is clear that as long as military R&D is not brought under control, disarmament negotiations will have little chance of success.

We need urgently to open a large public debate on the role of military R&D—to question its utility and its place in society, and to change priorities and directions in the field of research and development. ■

Notes

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3. Cf. *Report of the UN Secretary-General on the Economic and Social Consequences of the Arms Race and its Extremely Harmful effects on World Peace and Security. Replies Received from Governments*, 12 September 1977 (United Nations Document A/32/88, Add. 1).
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7. See Herbert F. York and G. Allem Greb, 'Strategic Reconnaissance', *The Bulletin of the Atomic Scientists*, April 1977; and Herbert York, *The Origins of MIRV*, Stockholm, 1973. (SIPRI Research Report, 9.)
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13. A table showing 'Peaceful Uses of Military Research and Development' can be found in *Disarmament and Development, Report of the Group of Experts on the Economic and Social Consequences of Disarmament*, New York, United Nations, Department of Economic and Social Affairs, 1972.
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A political analyst specializing in war history and military affairs offers a view, somewhat tendentious, of the dynamic relationship existing between advancing military technology and the difficulties inherent in maintaining peace and international harmony.

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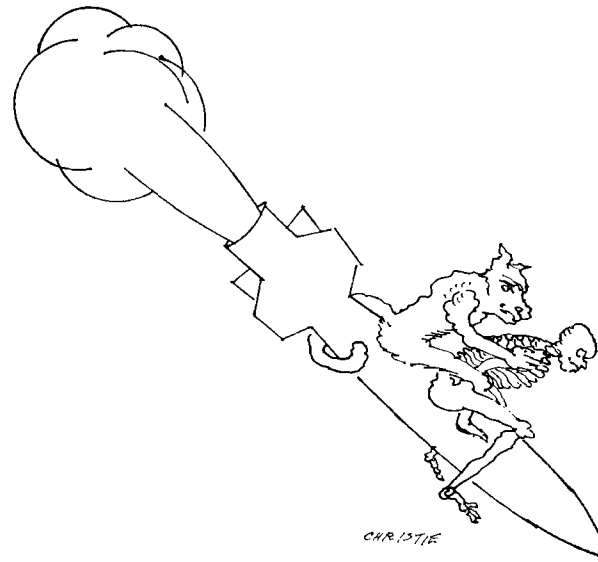
Scientific and technical progress and disarmament

V. M. Kulish



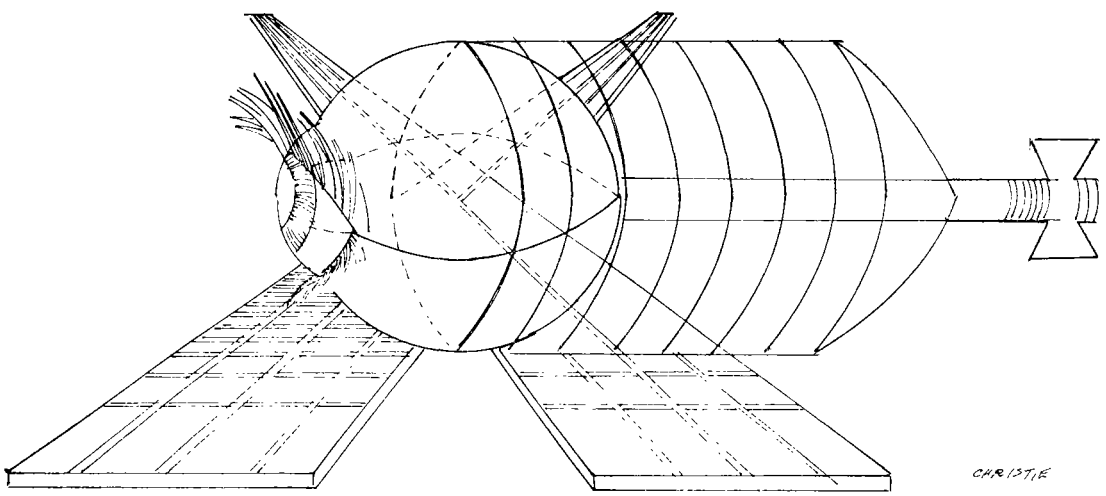
Vasiliy Mikhailovich Kulish, a graduate of the M. V. Frunze Military Academy and now a colonel in the reserve, holds a doctorate in history. A senior researcher in an institute of economic research, Professor Colonel Kulish is the author of two books and a past contributor to impact *(Science and Warfare, Vol. 26, No. 1/2, 1976). His address is: c/o Institut Ekonomiki Mezhdunarodnoi Sotsialicheskoi Sistemi, Akademia Nauk SSSR, Moskva, USSR.*

The scientific and technical revolution affected first of all the development of those countries in which it originated, i.e. those with a high level of scientific and industrial development and a considerable economic potential. It then began to spread to all countries of the world, drawing them to a greater or lesser extent into the process of world progress. Its effects are not uniform for all countries and depend on their level of development and their capacity to absorb scientific discoveries and technological innovations. Broadly speaking, scientific and technical progress has brought about radical changes in industry and in the economic, social and political life of states and peoples.

However, as the well-known American physicist Ralph Lapp once remarked: 'To scientists, the tragedy of our age is that at the very time when science has reached a position where it can enormously improve man's life, its main thrust has been turned to destructive applications.'[1] The tragedy referred to by Lapp has taken on a particularly ominous meaning in our own time. The scientific and technical revolution has led to an increase in the means of destruction and mass annihilation unprecedented in history, and notably to the development of nuclear and thermonuclear weapons.

The invention of the jet engine was used to create the means of delivering powerful nuclear charges, from tactical bombers and missiles with a range of a few hundred kilometres, to strategic and intercontinental bombers and missiles. Any point on the territory of a particular state, whatever its geographical position, can be selected as a target for weapons of this kind. Military electronics cover such fields as radio communications, television, radar, radio-navigation, radio-astronomy and radio remote control. It also provides the basis for sonar detection, infra-red radar, radio-meteorology, infra-red technology and various types of computer. It has facilitated the development of reliable strategic and tactical guidance systems as well as systems for bringing nuclear missiles and other weapons to their targets with extreme accuracy over any distance.

Conventional weapons have also undergone far-reaching changes. They have not only become more sophisticated and complex, but in their destructiveness and hitting power they more and more resemble nuclear weapons. All this demonstrates that the military application of the achievements of



science and technology has revolutionized warfare. At the same time, great changes are taking place in the science of war, particularly in military strategy.

Armaments improve constantly

The creation of nuclear and thermonuclear weapons and delivery vehicles of a strategic nature has directly affected the interrelation between politics and military strategy, which have, as it were, drawn closer together. In former times, before the appearance of nuclear weapons, progress in armaments did not directly influence state policy or international relations. It had no independent impact where foreign policy was concerned. Its role in foreign policy and international relations was a part of the whole system of military preparations—the manufacture and stockpiling of weapons, measures to reorganize the armed forces and increase their battle-readiness, the mobilization of a nation's entire manpower and resources and the militarization of its whole life—all of which together made it possible to calculate the likely impact of military action should it take place.

The creation of weapons of mass destruction, primarily nuclear weapons, has considerably heightened the role of armaments in international relations. The very fact of the emergence of such weapons in the United States increased the risk of another war and constituted a direct military threat to the Soviet Union and all other countries. The use of the atom bomb, without any military justification, against the Japanese cities of Hiroshima and Nagasaki at the end of the Second World War, was a demonstration of the United States' ambition to be the world's top nation.

Seeing the destructive power of nuclear weapons, the dangers of nuclear warfare cannot be exaggerated. Consequently, any decision or practical step to develop, produce and, above all, deploy weapons of this type and their delivery vehicles is of immediate relevance to both military strategy and international politics. For instance, the development by the United States of the neutron bomb and the cruise missile, the adoption by the United States of a vast programme for the construction of new strategic weapon systems—the mobile intercontinental MX missile, the Trident-II nuclear submarine, the strategic B-2 bomber and other types of weapons of mass destruction, as well as the NATO decision to deploy the American Pershing-2 missile and cruise missiles in Europe—together constitute a serious act of foreign policy, with repercussions for the policies of all states.

Under the influence of scientific and technical progress, armaments are being improved all the time, while weapon systems succeed each other with ever greater frequency. The development, production, stockpiling and deployment of modern weapons have become increasingly expensive. Year by year, the arms race goes on intensifying, devouring an ever greater share of national expenditure. At the present time, military expenditure by all countries of the world amounts every year to approximately $400,000 million, while the amount spent on the arms race from the end of the Second World War until 1978 has been estimated at $6 million million, which is roughly equal to the overall gross national product of all countries for 1976. It estimated that world military expenditure for 1980 will have reached $8 million million.[2]

Setting the pace for the arms race, the United States is planning to increase its military budget from $124,800 million in 1979 to $158,700 million

in 1981 and $248,900 million in 1985 (at current prices) [3]. As can be seen from the example of the United Kingdom, the NATO decision to increast military expenditure by 3 per cent per year has not only been achieved bue exceeded. The arms race is thus restricting opportunities for economic growth and the solution of social problems. It should be noted that world expenditure on the arms race is 1.5 times higher than expenditure on education and 3.5 times higher than that spent on medical care.[3]

The task we face

Almost a quarter of all scientists and engineers are working in the military sector, which directly or indirectly gives employment to over 60 million persons.[4] These are all people whose skills could have been used to apply the achievements of scientific and technical progress in fields connected with raising the standard of living and improving the welfare of mankind. More and more money is spent every year on weapon research, technological development and procurement. In the United States, for example, expenditure on military research and development under the Defense Department budget alone (in constant figures) topped $7,000 million in 1964 and should exceed $13,500 million in 1980 and 16,500 million in 1981. The corresponding figures for arms purchases in those years are $15,028 million, $35,368 million and $40,546 million.[5] All this is taking place at a time when the potential for destruction stockpiled in the world's arsenals is sufficient, if unleashed, to jeopardize man's continued existence on earth.

It is common knowledge that over the last thirty-five years the United States has taken the lead in the arms race. As a general rule, that country has been the first to introduce new strategic systems, its official announcement of their development, testing, production and deployment being nothing more or less than a show of strength. These shows of strength have occurred every eight to ten years. This was the case at the end of the 1940s and the beginning of the 1950s when the United States introduced nuclear weapons and the North Atlantic Treaty Organization was set up. They were then repeated during the 1950s with the deployment of the new American strategic B-52 bombers, and during the 1960s, when the United States deployed its intercontinental ballistic missiles and ballistic missiles launched from nuclear submarines. Each time, this was accompanied by lucubrations on the Soviet military menace and hypocritical statements about the military weakness of the West in the face of the deadly threat from the East. Later, of course, it turned out that the balance of power had not been upset and that the United States had not lost its lead in the arms race. By that time, however, the projected military programmes had already been adopted and the arms race spiral had taken another turn still more dangerous for peace.

The tasks facing us today include: (a) halting any further military applications of scientific and technical discoveries; (b) terminating the arms race and banning the quantitative and qualitative buildup of weapons; (c) working out a practical solution to the problem of reducing armed forces and armaments and finding a means of achieving complete disarmament.

The urgency of these problems is becoming increasingly apparent, although when practical measures to solve them are put forward, they meet with opposition from powerful forces who regard the permanent buildup of armaments and military strength as a fundamental prerequisite for a policy

based on a 'position of strength', or who obtain vast profits from armaments production. To justify their attitude they employ a variety of arguments, including some based on conclusions drawn from an appraisal of contemporary scientific and technical progress.

Is scientific and technical progress to blame?

The mass media in the Western countries give wide currency to the fact that the latest scientific breakthroughs are first introduced in the military field and only afterwards find applications in civil industry and life. On these grounds, it is concluded that the development of military technology and armaments stimulates progress in general, and scientific and technical progress in particular. Arthur Burns, an economist and former adviser to the President of the United States, asserts that the military system has left its mark on both the structure and functioning of the economy. Its influence is all-pervasive. Some defence-orientated branches of industry, such as aerospace, electronics and communications, have become decisive factors in the economy and their development has been beneficial to many regions, for example, Los Angeles, San Diego, Seattle and Baltimore [4]. James A. Donovan, the author of a book on American militarism published in the United States, writes that industrial sectors and companies working on military contracts have become the most powerful monopoly producers of goods and services in the United States.[6]

One of the reasons for this is that the armaments industry allows many scientists, engineers, technicians and workers to gain rapid promotion, earn high salaries and display their creative abilities in the design and development of weapons. In addition, the production of armaments, particularly weapons of mass destruction and their delivery vehicles, is spread among numerous specialized sectors. Many scientists working on gyromechanisms, on micro-miniaturized electronics or on plasma physics do not always realize that they are creating monstrous machines of destruction. They regard their work purely as a means of earning a living. All this helps to blunt people's perception of the danger of the arms race.

Although it is frequently pointed out that, by stimulating the development of some branches of industry, weapons production in the United States and other countries inhibits to some extent the growth of other branches, the beneficial effect of the armaments industry on science, technology and the economy is not contested. 'Not even the great destruction of World War II was sufficiently disillusioning to put a brake on technology; indeed, the war accelerated it.'[7]

Such one-sided judgements would be of purely academic interest, as examples of the distortion of the link between scientific and technical progress and the arms race, were it not for the fact that they are used as 'proof' of the inevitability of this link, of the powerlessness of men and nations to do anything about it and of their inability to halt the arms race and achieve disarmament. Furthermore, these arguments endeavour to absolve the real culprits—imperialist and militarist circles—of all responsibility for the arms race and military preparations and to place it on other shoulders. Ralph Lapp's conclusion is significant in this respect: 'The guilt of killing is spread so thin—shared so universally—that it no longer seems personal. . . . No one, then, is responsible—and everyone is responsible. We

cannot single out the scientists, or the politicians, or even the military, as the villains of our danger.'[8]

A quest for domination

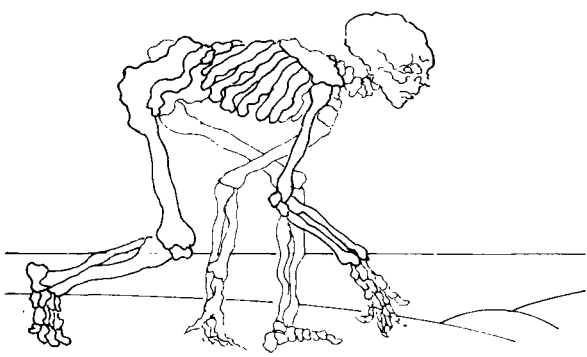
What then is the nature of the link between scientific and technical progress and the war industry? Science, of course, has always been linked with industry, serving it and satisfying its development needs. Industry is therefore a major stimulus for scientific and technical progress. In the modern world, science has reached a level of development at which it is more and more closely associated and even identified with industry, while the applied sciences are becoming a most important part of the production process.

Scientific discoveries and technological developments have led to major industrial changes, e.g. nuclear power is becoming more widespread, completely new branches of industry have arisen, agriculture is becoming increasingly intensive, international and national transport is expanding, and new management methods are being introduced.

Nevertheless, priorities for the use of scientific discoveries are dictated by policy, and, to be more precise, by military policy. A state pursuing the goal of establishing world domination, or securing a leading role for itself in the world, aspires to superiority in all respects, but chiefly in the military sphere. The statements made by President Carter that the goal of his administration was to ensure that the United States would always remain the strongest or leading nation in the world in military and economic terms were not just rhetoric designed to impress the nationalistically minded man in the street. Such statements are backed by actual programmes to strengthen the military might of the United States and NATO, to intensify military production, to ensure a steady increase in military expenditure, and to improve the strike capacity and mobility of the armed forces. In conformity with this policy, Washington lays down basic guidelines for the development of the country's military power, priorities for the buildup of the different services, the specific deadlines to be met, and the quantities to be provided.

National policy as catalyst

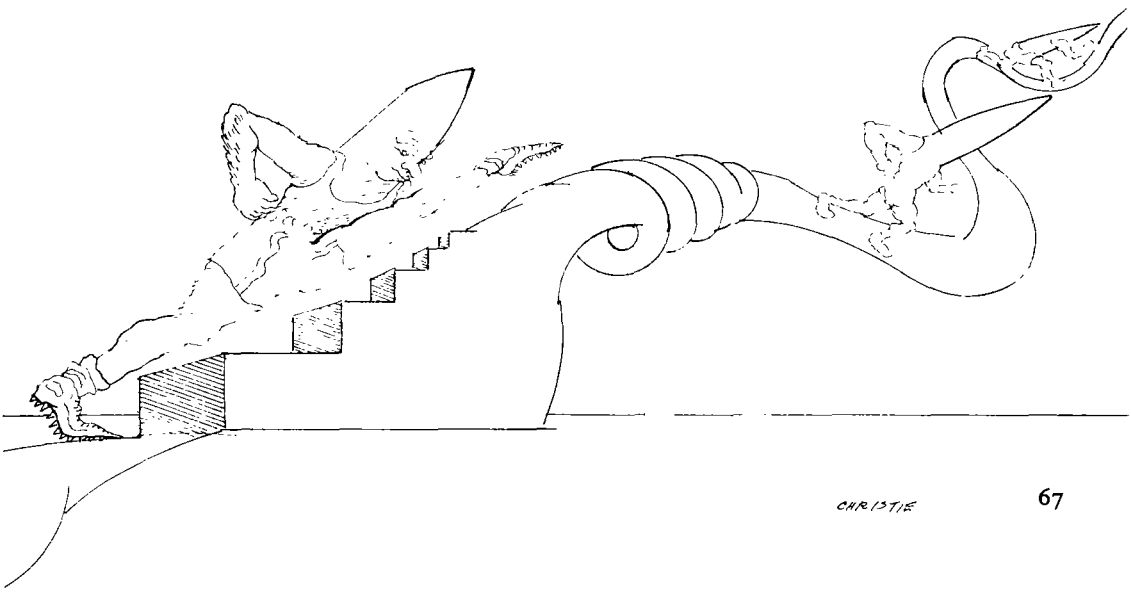
In the 1940s and 1950s, for instance, the United States political authorities based their foreign policy on a monopoly of nuclear weapons and gave top



priority to a rapid buildup of nuclear forces. When it became obvious that the policy of nuclear monopoly had failed, they set themselves the goal of achieving military superiority over the Soviet Union by rapidly deploying a strike force of strategic nuclear missiles and by raising the fighting capacity of their conventional non-nuclear forces. During the 1970s, particularly in the latter half, when this policy, too, failed to produce the desired results in the conflict with the socialist countries and in the struggle against national liberation movements, they attempted, in addition to building up the strike power of the triad of strategic forces (intercontinental ballistic missiles, ballistic missiles launched from nuclear submarines, and strategic bombers armed with cruise missiles), to set up a system of strategic strong points in key areas of the world, and a rapid response force capable of making a lightning response to developments anywhere in the world.

The United States Government presents Congress each year with a general report, prepared by the Pentagon, substantiating the procurement programme for weapons and military technology, the programmes for research and development, the testing and evaluation of new weapons, and the relevant financial expenditures. In addition to this general report, Congress also receives a special report on military R&D. Special congressional committees approve both the programmes and their financing. Companies working under military contract carry out research on the creation and modernization of armaments, and develop the technology for manufacturing them. Finally. the country's political authorities use the resources of the mass media to provide ideological support and propaganda for the policy of the arms race. Research institutes and scientists active in the natural and social sciences are also involved in this work.

Thus there is no direct, automatic link—much less an inevitable one—between scientific and technical progress and weapon manufacture and the arms race. The go-between is national policy which, in accordance with its aims, can compel both science and industry to work on behalf of war. It is policy alone, decided upon by the actual political leardership of a



country, that bears the entire responsibility for determining the goals, nature and scale of the production, stockpiling and deployment of armaments, and for the entire system of military preparation. The notion of a direct link between the scientific and technological process and the arms race is used to conceal and justify the activities of those governments which, conducting policies based on a position of strength, refuse to put a stop to the arms race and on various pretexts decline to take effective practical measures to reduce armed forces and armaments and to achieve disarmament.*

What prevents disarmament?

International détente, particularly in the second half of the 1970s, created a favourable international political climate for settling the disarmament problem. Progress with détente and the continuation of the arms race and military preparation became increasingly incompatible.

As always, the initiative for raising the issue of disarmament at international forums was taken by the Soviet Union and other states of the socialist community. As a result, a series of treaties and agreements were signed, including the treaty banning nuclear-weapon tests in three environments, the treaty on the non-proliferation of nuclear weapons, and the treaty on the prohibition of the emplacement of nuclear weapons and other weapons of mass destruction on the sea-bed and the ocean floor and beneath.

International relations were greatly improved by the treaties banning the use of the Antarctic for military purposes and outlawing nuclear weapons in Latin America, the Soviet–American memorandum establishing a direct communication link between Moscow and Washington, and the co-operation agreement on the peaceful uses of outer space.

The convention on the prohibition of the development, production and stockpiling of bacteriological and chemical weapons and on their destruction, and the convention on the prohibition of military or any other hostile use of environmental modification techniques were signed.

Soviet–American Strategic Arms Limitation Talks (SALT) led to the signing of the treaty on the limitation of anti-ballistic-missile systems, which was supplemented two years later by a protocol, the interim agreement on certain measures with respect to the limitation of strategic offensive arms, and a number of other important documents.

All these treaties and agreements narrowed to some extent the area of material preparations for a new world war and created pre-conditions for limiting the arms race in respect of certain types of nuclear weapons and their proliferation. In recent years, however, the situation has changed.

The second stage in SALT lasted approximately seven years and culminated in the signing of an agreement on the limitation of strategic offensive arms, ratification of which has been indefinitely postponed on the American side. Talks on the mutual reduction of armed forces and armaments in Central Europe, which opened on 31 October 1973, are still going on and have led to no results whatsoever. The Soviet–British–American talks on a comprehensive nuclear weapon test ban have also dragged on for many years. The Soviet–American consultations on the limitation of arms sales

* The author's description of national motives is applicable to a number of nations—Ed.

and transfers took place more than a year ago and have not been renewed. The first round of talks on limiting the development of anti-satellite systems was completed in June 1979, but a date for the next round has still not been fixed. Discussions on the limitation of military activities in the Indian Ocean were suspended in February 1978.

The United States and other NATO countries are constantly building up their forces in Central Europe, including the area covered by the reduction of armed forces and armaments. American armed forces are being rapidly reinforced in the Indian Ocean and the Persian Gulf. The arms trade is not being cut back either, nor is the transfer of arms to other countries, taking place in the form of the provision of military assistance. The flow of American weapons is mainly directed towards the Middle East and the countries of Latin America.

'Assured destruction' and the 'hawks'

The forces engaged in continuing the arms race, conducting a policy based on a position of strength and making profits from arms manufacture and trade have taken advantage of scientific and technical progress to neutralize the consequences of the limitations imposed by the various treaties that have been concluded. By transforming its ballistic missiles into MIRVs during the period from 1969 to 1979, the United States doubled the number of its nuclear warheads (to 11,000) and improved their accuracy, while at the same time slightly reducing the number of launchers from 2,270 in 1969 to 2,142 in 1979.[9] With its plans to equip the B-52 bomber fleet with cruise missiles, the United States Government intends to achieve a considerable increase in the strike power of its strategic air force and of its whole strategic triad, including land-based intercontinental ballistic missiles, nuclear-submarine-launched missiles and the strategic air force. Naturally enough, the other side—the USSR and its allies—has been obliged to take countermeasures to strengthen its own defence capacity. As a result, the effectiveness of measures to curtail strategic armaments has in no way kept pace with the speed and intensity of the arms race. What is the basic reason for this disparity?

The driving force behind weapons production is the policy based on a position of strength pursued by the United States and other Western powers. Its underlying principle today is the doctrine of assured destruction. The theoretical propositions, policies and doctrines were formulated in the United States and subsequently adopted as a guide by its NATO allies and Japan. No secret was made of their anti-Soviet and anti-socialist bias.*

The doctrine of assured destruction is advantageous to the ruling circles in the United States and its allies because it enables them to justify the constant buildup of military power, which they present as an inescapable necessity in order to ensure their own national security. Intensifying the ever-spiralling arms race, Washington presents it as a series of countermeasures to the military threat posed by the Soviet Union. On this subject, the former Secretary of State Henry Kissinger writes:

* None of the instruments in question specifies the term 'anti-socialist'—Ed.

> Remarkably, the doctrine of 'assured destruction', espoused by liberal advocates of arms control who were supposedly most moved by humanitarian concerns, implied the most inhuman strategy for conducting a war. The reasoning was that the more horrible the consequences of war the less likely we were to resort to it; the more controllable its consequences the greater the risk that a war would actually occur.[10]

This very argument is used to support the policy for averting world war being widely publicized in Western countries. The more intensively NATO member countries prepare for war, the more certain it is that war will not break out. This view is being actively canvassed not so much by liberals and 'doves' as by conservatives and 'hawks', since it is the window-dressing for the policy of 'containment by terror'.

The policies of the Soviet Union and other states of the socialist community are based on the historically proven fact that, in addition to being highly expensive, the manufacture and stockpiling of weapons and military preparation not only do not eliminate the danger of war but, on the contrary, constantly maintain and aggravate it. If the arms race is not halted, it will not only bring to an end any extension of political détente in relations between states but, more seriously, may even reverse the whole process. The programmes adopted in recent years by the United States and NATO for building up their military strength and for rearmament indicate that the threat of such a reversal has already become a reality.

Measures to curb armaments

Mankind is faced with this choice: either the arms race will be halted and states will proceed to disarm, systematically and gradually reducing the threat of world war and switching ever increasing material and intellectual resources to applying the achievements of science and technology to economic development, higher living standards and the solution of social problems, or the system of military preparations will consume more and more of the resources vital to human existence and the threat of armed catastrophe will loom still larger.

The attitude of the Soviet Union and the other states of the socialist community to this choice is a simple one. They relentlessly and consistently fight for the peace and security of peoples, for a halt to the arms race and for disarmament. The peace programme adopted at the Twenty-fourth Congress of the Communist Party of the USSR and further developed at its Twenty-fifth Congress, which was unanimously supported by all the fraternal parties of the socialist countries, contains practical proposals for halting the arms race and achieving disarmament. These proposals form the basis for the USSR's foreign-policy approach to the solution of these issues.

The Soviet Union and the other states of the socialist community consider that, under present circumstances, the most important elements for agreed state action in the field of disarmament are the following: halting the nuclear arms race; limiting and subsequently destroying nuclear weapons; banning nuclear-weapon tests in all environments; strengthening the nuclear non-proliferation system; banning and destroying chemical-weapon stockpiles; prohibiting the development of new types and systems of weapons of mass destruction; reducing armed forces and conventional armaments; creating a zone of peace in the Indian Ocean, the Mediterranean and other areas as

well as nuclear-free zones; cutting back military budgets; reducing military confrontation in areas of high military tension and conflict; urgently and peacefully settling conflict situations; and strengthening the international legal principle of renouncing the use of force or the threat of force in international relations.

The opponents of disarmament frequently resort to slanderous fabrications regarding the threat from the East, the military superiority of the Soviet Union and the gap in military readiness between the United States and other Western powers and the USSR and the Warsaw Pact countries. But the most frequently heard argument relates to the difficulty or impossibility of monitoring in a reliable and trustworthy way the compliance of the parties with the treaties and agreements concluded between them.

The verification problem

Monitoring and checking compliance with any international treaty or agreement is indeed a complicated business. The problem is one of obtaining reliable, continuous and highly accurate evidence that treaties are being honoured by their signatories, without infringing such principles of international law as sovereignty, territorial integrity and non-interference in domestic affairs. No state can permit the checking and monitoring of international treaties to be used for espionage or for undermining its security.*

Scientific and technical progress enables the partners to a treaty to create and make widespread use of effective means for mutual monitoring; they are grouped under the general heading of 'national technical means'. These means were first mentioned and received international legal recognition in the treaties on the limitation of strategic offensive and defensive weapons concluded between the USSR and the United States in May 1972. The use of modern photography, radar, infra-red technology and radio communication in earth-based, airborne and space observation systems makes it possible to obtain sufficient information for assessing whether the parties to a treaty are fulfilling their commitments under it.

Although the constant improvement of armaments and military technology, as well as means of defending and camouflaging them, places certain obstacles in the way of monitoring by 'national technical means, the refinement of instruments and methods of observation makes it possible to overcome difficulties as they arise and to identify in good time, activities inconsistent with the terms of a treaty. Difficulties may also arise as a result of deliberate jamming by one side or the other. Advantage is taken of these difficulties by the opponents of disarmament to claim that monitoring methods are not sufficiently reliable and so either to refuse to ratify a particular treaty or agreement or to attempt to force upon the Soviet Union and other countries of the socialist community or neutral states methods of verification that would constitute an infringement of their sovereignty. The Western powers, for example, block all proposals by the socialist states at the Vienna talks on the reduction of armed forces and armaments, on the grounds that they have no reliable information on the number of troops maintained by the Warsaw Pact countries in the region concerned and are

* Some states have repeatedly offered to invite foreign specialists to visit their territory and verify, by their own instrumentation, adherence to treaty agreements.—Ed.

unable to obtain it without on-the-spot checks. One of the objections to the ratification by the United States Senate of the Soviet–American Strategic Arms Limitation Treaty (SALT II) is based on the allegation that since losing the United States observation posts in Iran, Washington can no longer reliably monitor implementation of the treaty using national technical means.

A call for vigorous action

In fact, the verification problem arises less from the degree of effectiveness of the national technical means available for monitoring purposes, than from the cold-war legacy of mistrust and suspicion in relations between countries with different social systems, and from the constant fuelling of this mistrust and suspicion by the opponents of international disarmament and by the mass media of the Western countries. Consequently, if the confidence-building measures first outlined at the Conference on Security and Co-operation in Europe were to be extended and made more effective, this could considerably reduce any opportunity for using the verification problem as a means of opposing disarmament and détente. The holding of a European conference on disarmament, as proposed by the Warsaw Pact countries, could lead to substantial progress on these measures for building confidence in relations between the European countries, thereby facilitating the solution of the disarmament problem.

The problems of disarmament in the context of a certain deterioration in international relations and the building up of an alarming situation in Europe are thus acquiring even greater urgency. These problems must be solved in the interests of preserving peace, averting war and halting the arms race. Scientists, scientific assistants, engineers, technicians and other workers, who are the fundamental driving force of scientific and technical progress, have created a powerful scientific and material basis for successfully resolving the disarmament problem. By vigorous action and systematic struggle, they can do a great deal to prevent a new war and to secure the halting of the arms race, the adoption of urgent measures to limit armaments, the continuation of the process of international détente and the development of international relations in a spirit of collaboration and mutual understanding. ■

Notes

1. R. Lapp, *Kill and Overkill*, London, Weidenfeld & Nicolson, 1962.
2. A. Vakhrameev, *Bor'ba socialističeskogo sodružestva za razrjadku meždunarodnoj naprježennosti*, (The Struggle of the Socialist Community to Achieve Détente). Moscow, 1979.
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If there were no military R&D, no new major weapons would be produced and no significant improvements would be made in the performance of existing arms. In a qualitative sense, the arms race would come to a halt, even though the size of arsenals might grow and those of the smaller powers might be aligned technologically more closely with those of the great powers through the arms trade. It is hard to avoid the conclusion that those most directly responsible for the arms race are the specialists involved in military R&D.

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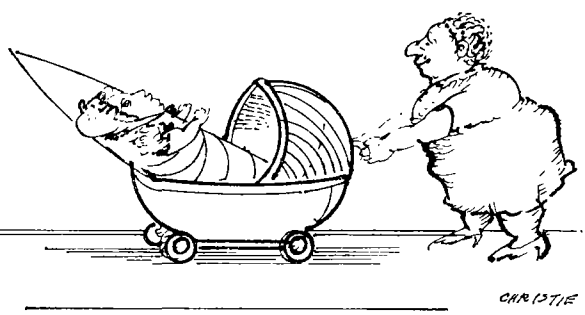
Social and economic reverberations of military research

Frank Barnaby



A physicist, Dr Barnaby worked for the Atomic Energy Authority of his native United Kingdom from 1950 until 1957, when he became a senior scientist attached to the Medical Research Council, serving there almost twelve years. From 1968 until 1970, he served as executive secretary to Pugwash Conferences on Science and World Affairs. Since 1971, this author or director of many publications dealing with arms control and disarmament has directed the Stockholm International Peace Research Institute. Address: SIPRI, Sveavägen 166, 113 46 Stockholm, Sweden. Telephone 08-15 09 40.

The Soviet-American arms race is out of control. Unless it is soon brought under control, it is hard to see how a nuclear world war can be avoided. The momentum of advances in military technology is a, if not *the*, major reason why the nuclear arms race is out of control and the probability of nuclear war increasing. Military R&D impels military technology and is, therefore, the activity most responsible for the armaments race.

Resources devoted to military R&D

Data on the global resources devoted to military R&D have been published by the Stockholm International Peace Research Institute (SIPRI). Although these data relate mainly to the 1960s, there is no reason to believe that the basic patterns of military R&D have changed much since then.

During the 1960s, according to SIPRI's estimates, an average of about $16,000 million a year was spent on military R&D, about 10 per cent of world military expenditure. Now, roughly $50,000 million a year is spent on military R&D, also about 10 per cent of world military expenditure. Even these huge sums are likely to be conservative estimates.

In constant prices, to take inflation into account, world military R&D spending probably rose by about 60 per cent during the 1960s and by about 20 per cent during the 1970s. Judging by the increases in military spending planned by some major countries, military R&D spending is likely to increase more rapidly during the 1980s than during the 1970s.

Before the Second World War, the use of scientists to develop new weapons and improve old ones was very limited. In the United States, for example, the money given for military R&D amounted to less than $5 million a year until the late 1930s. During the war, the funds grew from about $30 million a year to roughly $1,500 million a year. In the first few years after the war, the funds devoted to military R&D in the United States dropped, according to SIPRI figures, to about $700 million by 1948, and then started to climb again. The trend has been upwards ever since. By 1950, the total sum available for American military R&D reached $1,000 million; by 1955 it had reached $3,000 million; by 1958, $5,000 million; by 1960, $7,000 million, by 1967, $9,000 million; and so on, until today's figure of about $18,000 million.

What the big powers spend

In real terms, American spending in military R&D has increased about sixfold since 1950. During the past few years, however, military R&D expenditures have, in real terms, remained roughly constant. But new increases are planned for the next few years.

Much less is known about military R&D spending in the Soviet Union. The SIPRI study claims that during the 1960s the Soviet effort was somewhat less than that of the United States. Whereas the United States accounts for about a half of total world military R&D expenditure during the period, the USSR is said to account for about one-third. Given that the arsenals of the two powers are now roughly comparable in most respects—although the United States still has a very pronounced overall technological edge over the USSR, it is probable that the Soviet Union has devoted relatively more of its resources to military R&D during the 1970s than it did during the 1960s.

Until the end of the 1960s the United Kingdom spent considerably more than France on military R&D. But by 1970 the French had caught

up with the British, and both countries were spending about 10 per cent of their military budgets on R&D. At that time each spent about $540 million, compared with about $9,200 million in the United States. During the 1970s, British military expenditure (in constant prices) increased 1.23 times, and French 1.31 times—to about $16,000 million a year and $19,000 million respectively. Each country is, therefore, now probably spending about $1,800 million a year on military R&D.

By 1960, the Federal Republic of Germany had become the fifth biggest spender on military R&D, coming just after the People's Republic of China. During the 1960s, the Federal Republic of Germany military R&D spending increased, in constant prices, about 4.25 times, so that by 1970 it was spending about $314 million, or about 5 per cent of its military budget. It is still spending about the same proportion of its military budget on R&D, so that current Federal Republic of Germany R&D expenditure is about $1,100 million a year.

China's spending on military R&D is even more of a mystery than its military budget in general. SIPRI's estimate of current Chinese military spending, admittedly a very rough one, is about $45,000 million a year. Of this, China probably spends considerably less than $1,000 million on military R&D.

China's defence industry was established at the end of the 1950s. The weapons manufactured are mostly copied from Soviet designs—apart from some armoured vehicles and some warships, as well as China's nuclear weapons and their missile delivery vehicles. Consequently, the resources devoted to military R&D have been relatively small. No attempt has been made to develop a full range of indigenously designed conventional weapons.

It is unlikely that China spent, on average, more than $100–200 million a year on military R&D during the 1960s and probably even fell behind the Federal Republic of Germany during the 1970s. China may, of course, spend considerably more on military R&D as its defence modernization programme gets under way.

What other powers spend

World military R&D spending had reached $12,000 million a year by 1960, over $15,000 million a year by 1965, nearly $20,000 million a year by 1970, about $26,000 million a year by 1975, and was about $50,000 million in 1980. (In real terms, world military R&D expenditure has about doubled since 1960., Ruth Leger Sivard, an American expert on military and social expenditures) has calculated that between 1960 and 1979 the total outlay on military R&D exceeded $370,000 million.

For the past two decades the bulk of military R&D has been done by the United States and the USSR. These two countries account for about 85 per cent of the money spent on this activity. France, the United Kingdom, the Federal Republic of Germany and China together spent about 20 per cent as much as the United States. The rest of the world accounts for no more than 5 per cent of the total spent on military R&D. Of this group, the most significant spenders are Australia, Canada, India, Italy, Japan, the Netherlands and Sweden. The amount spent by Warsaw Pact countries on military R&D is not publicly known.

In general, countries with the biggest defence industries spend the most on military R&D. The current trend is for more and more countries,

including Third World nations, to establish defence industries. We can expect, therefore, that military R&D spending in these countries will sharply increase. Moreover, in today's world, each generation of new weapons costs considerably more to research and develop than the last.

The money spent by governments on military R&D is a large fraction of the money they spend on R&D in general. In the United States, and almost certainly in the USSR as well, over a half of the total government-financed R&D is military. For the world as a whole, about 40 per cent of research and development expenditure is devoted to military research.

Until the early 1960s, this percentage was much higher. In the United States, for example, throughout the 1950s more than 80 per cent of government R&D funds went to military R&D. In the United Kingdom, the percentage during this period was over 70. By 1970, the percentage of government R&D funds devoted to the military in the United States had dropped to about 54; in the United Kingdom it had dropped to about 40. In France, the figure for 1970 was 32 per cent, and in the Federal Republic of Germany about 17 per cent. These percentages have remained roughly the same during the 1970s.

According to the 1978 United Nations publication, *Economic and Social Consequences of the Arms Race and of Military Expenditures*, about 60 million people (equivalent to the entire labour force in the manufacturing industries of Europe) are engaged in military or military-related occupations. About 26.3 million of these are in the armed forces.

Many of the people working for the military are highly qualified. The most highly qualified are those working in R&D. The United Nations report suggests that military R&D absorbs scientific and technological capabilities ten times as great as those available to *all* the developing countries. About 400,000 of the world's most highly qualified physical scientists and engineers work on military R&D; this number is about 40 per cent of the world's research scientists and engineers. If only physicists and engineering scientists are included, the percentage is even greater—well over 50.

Social and economic consequences of military R&D

The use of such a large proportion of the world's scientists and engineers exclusively for military R&D has global and national economic and social consequences and is, in its effects on the arms race, a direct threat to world security.

The global economic and social consequences have not yet been studied in detail. Nevertheless, the United Nations report is quite clear about them in general terms. It points out that the problems of industrialization and of growth in the Third World—of dealing with the population explosion, the food crisis, natural disasters and the effects of war, of pollution, of developing new sources of energy and raw materials while preserving currently available resources, of urbanization, as well as the problems of reducing poverty, of improving standards of health, diet, education and housing—all these 'make claims on investment, research and other resources in direct competition with military claims'. Resources used for military purposes are lost for civil ones.

The opportunities for development lost by the diversion of resources to

military R&D are, the report explains, so many, differentiated, and unpredictable, that an adequate description of them cannot be given. But, so far as the economic and social problems raised by development are concerned, there are enormous needs 'unexplored in almost every respect, waiting to be dealt with in the systemic, large-scale, and purpose-oriented fashion' that has until now been confined mainly to military research. The skills tied up in military research are vital for, and could rather quickly be diverted to, such problems as the improvement of food supplies and their preservation, the development of new and more relevant sources of energy, the control of pollution, and the alleviation of natural disasters.

High proportion of military grants

There is a special need for the use of extra research capabilities for development because, it is now clear, the developing countries cannot simply adopt the technologies available in the industrialized world. Specific Third World solutions are needed for problems related to water supplies, energy supplies, agriculture, education, health, communications and transport. The expertise now concentrated in military R&D obviously could contribute crucially to all these fields. Research into and the development of suitable technologies for the Third World may be the most useful single contribution which disarmament (and, for that matter, the rich countries themselves) could make to development.

An excellent recent publication on the impact of military R&D on the national economy is the paper presented at the 1980 annual meeting of the American Association for the Advancement of Science by Lloyd J. Dumas, of the University of Texas. Professor Dumas, dealing with the situation in the United States, explains the difficulties of estimating precisely the number of American scientists and engineers employed in military R&D But he points out that in 1974, for example, 77 per cent of American research and development engineers and scientists (excluding social scientists) who received government support, received it from the Department of Defense, the National Aeronautics and Space Administration and the Atomic Energy Commission—more than 50 per cent from the Department of Defense alone. The same three agencies funded nearly 75 per cent of the engineers and scientists employed by business and industry who received government support. He concludes that substantially more than one-third of the 'engineering and scientific personnel' in his country are employed in the development of military-orientated technology, and have been for two or three decades or more.

'Spin-off' and productivity

Dumas convincingly lays the myth of the 'spin-off' from military to peaceful technology and points out the decline in the number of American innovations over the period 1953–73, compared with those of the United Kingdom, Japan, the Federal Republic of Germany and France. In this comparison, Japan and the Federal Republic of Germany do relatively well: not coincidentally, according to Dumas. These two countries 'spent, on average, about 3.3 per cent and 22 per cent respectively of government R&D expenditures on defense and space over the period 1961–72, as opposed to a[n American] average of 76.6 per cent'.

Re-investment for civil needs

Labour productivity is the key to economic success. Dumas describes the deterioration in American productivity over the past years. From 1947 to 1965, he says, output per labour-hour in the United States grew at an average annual rage of 3.3 per cent. From 1965 onwards, the rate of labour productivity averaged only 1.6 per cent a year. In recent years, American productivity has been the lowest of any major Western economy.

Moreover, Dumas argues, the productivity collapse is accelerating.

> While the annual growth rate for 1965–73 averaged 2.1 per cent, from 1973–78 it was 0.8 per cent. In the first six months of 1979, output per labour-hour in the private business sector actually *fell* at an annual rate of 3.3 per cent. During the second quarter of 1979, productivity fell at an annual rate of 5.7 per cent, the largest quarterly decline recorded since 1947.

Dumas has no doubt about the reasons for these alarming statistics.

> It is not the failure of technology as a whole that produced our present productivity problems—the [American] scientific and engineering community is not becoming less ingenious or less productive. Rather the collapse is a direct, inevitable, though long-term result of the decades-long diversion of a large fraction of the nation's critical scientific and engineering effort from productive [civilian] technological development [to military research and development].

The decline of American productivity has led to increasing inflation and high unemployment: the costs of American participation in the qualitative arms race. (Similar costs, even if different in detail, have been paid by the Soviet Union.) Given the relationship between economic power, international influence, and national security, the loss of the United States' economic power will inevitably lead to a drop in its security. Ironically, increasing efforts in military technology are damaging the very security that this technology is supposed to provide. It is hard to see how the United States can regain its economic growth potential and, hence, its economic power, unless it re-invests much of its military R&D in peaceful purposes.

The military R&D and the threat of nuclear war

An effort of the magnitude invested in military R&D cannot fail to produce staggering results. Let me give two examples. The atomic bomb dropped on Hiroshima exploded with an explosive power equivalent to that of about 12,000 tonnes of TNT. It weighed about 4 tonnes, so that the yield-to-weight ratio was about 3,000. The warhead about to be deployed on the American Minuteman III ICBM has an explosive power equivalent to that of about 370,000 tonnes of TNT and weighs only 0.1 tonne, so that the yield-to-weight ratio is nearly 4 million to 1—close to the theoretical limit.[1]

The Hiroshima bomb was dropped from a B-29 bomber with an accuracy that depended on the eyesight of the aimer of the bomb. On average this was so bad as to make it difficult to state the CEP. But a modern ICBM has a CEP of about 200 m over a range of about 15,000 km, and CEPs of a few tens of metres are feasible. Improvements in warhead design and accuracy indicate the incredible progress made by military technology over the past thirty-odd years. In the next thirty years we can expect technological revolutions in space warfare, the 'automated battlefield',

electronic warfare, military use of high-energy lasers, and many other new developments.

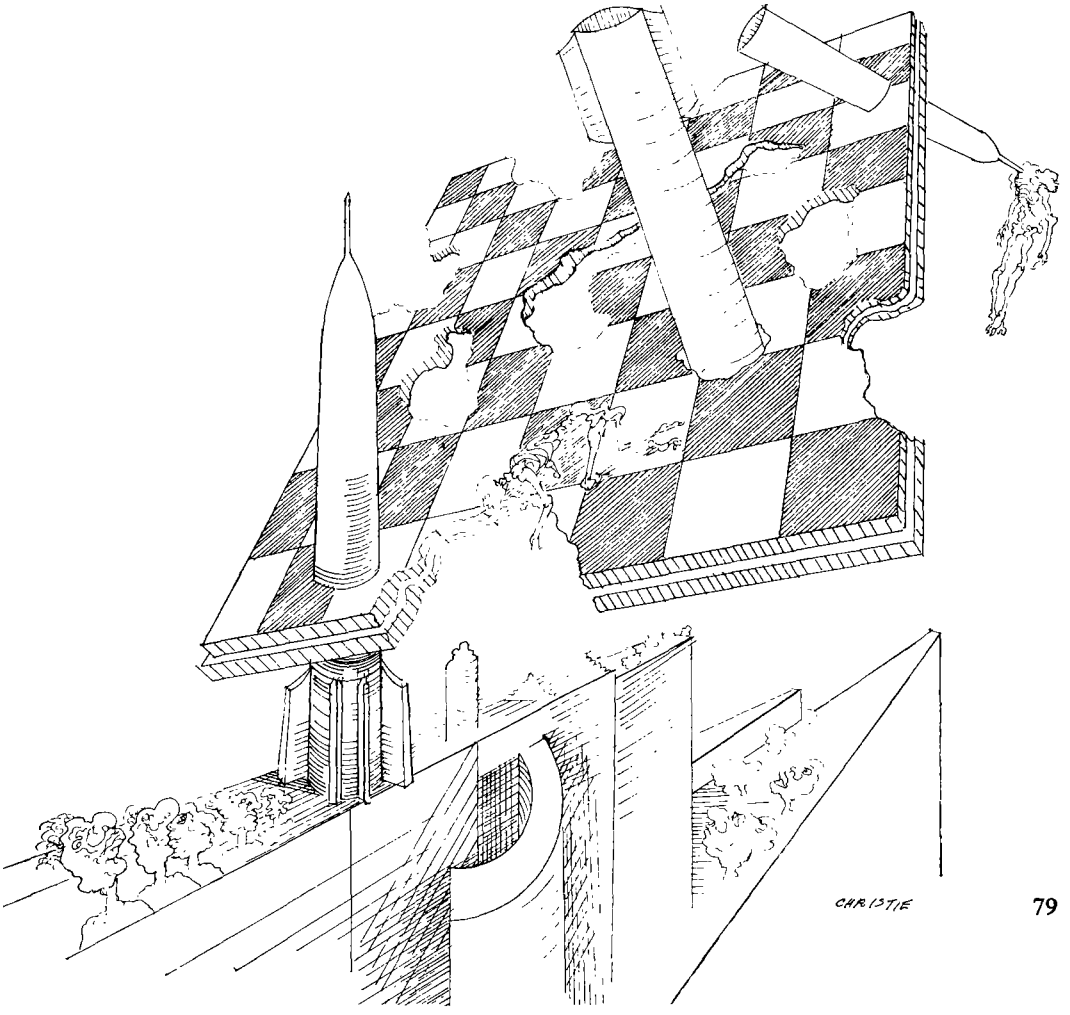
By far the most dramatic weapons to emerge during the 1980s will be certain types of nuclear weapons specifically designed for fighting a nuclear war. American and Soviet military scientists are now actively developing such weapons. Because of these weapon developments, a growing number of other specialists believe that the probability of a nuclear world war is increasing. The existence of weapons for a nuclear war is simply not suitable for deterring such a war.

We have heard much about some nuclear weapons—Soviet SS-20 medium-range ballistic missiles, American cruise-type and Pershing II missiles. These so-called tactical nuclear weapons are being, or are planned to be, deployed in Europe.

But strategic nuclear weapons suitable for fighting a nuclear war are also being developed. Some, like the American Mark 12A warhead for the Minuteman III, have been deployed.

How a war might ignite

It seems to me rather obvious that when many types of nuclear-war weapons are deployed, military tactics will be changed to accommodate them. And once the military become accustomed to the idea of fighting a nuclear war,



the leaders of the great powers will come to think of a nuclear war as 'fightable and winnable'.

A direct nuclear attack by one great power on another is not the most likely way in which a nuclear world war would begin—although the danger of the war beginning by accident of miscalculation is always present.

The escalation of a regional conflict to a general nuclear war is, I believe, much more likely. A future local conflict in a Third World region may begin as a conventional war and then escalate to a limited nuclear war in which the nuclear weapons of the local powers are used. This may, in turn, escalate to a full-scale nuclear war involving the two superpowers. Escalation may be most likely if these same powers are the main suppliers of the conventional weapons used in the original conflict. (And this is why both the international arms trade and the proliferation of nuclear weapons are so dangerous.)

A nuclear world war would be a catastrophe of unimaginable proportions. The existing nuclear arsenals of the United States and the USSR are, by any standards, huge. Their total number of nuclear weapons runs into the tens of thousands—probably upwards of 60,000.

American strategic nuclear forces are loaded with about 9,000 nuclear warheads, with a total explosive power equivalent to that of about 4,000 million tonnes of high explosive. Soviet strategic nuclear forces could deliver about 4,000 nuclear warheads, with a total explosive power equivalent to that of about 8,000 million tonnes of high explosive.

In the so-called 'tactical' nuclear arsenals there are several tens of thousands of nuclear warheads, each on average several times more powerful than the Hiroshima bomb. These add about another 4,000 million tonnes of high-explosive equivalent to make a total of about 16,000 million tonnes—equal to about one and a quarter million Hiroshima bombs. Put another way, the nuclear arsenals are equivalent in explosive power to about 4 tonnes of TNT for every man, woman and child on earth.

And what it might do

A nuclear world war in which all, or a significant fraction, of these weapons were used would almost certainly:

Destroy all the major cities in the Northern Hemisphere.

Kill most of the urban population in the Northern Hemisphere by blast and fire, and most of the rural population by radiation.

Kill many millions in the Southern Hemisphere by radiation from fallout.

The long-term consequences of a nuclear world war are unpredictable but may include:

A change in the global climate.

A serious reduction in the ozone layer which protects life on earth from excessive ultraviolet radiation.

Severe genetic effects from radiation.

No scientist can assure us that human life would survive these effects, yet the nuclear arsenals are still being augmented quantitatively.

But qualitative developments in nuclear weapons, particularly those that improve nuclear-war capabilities rather than deterring war, are much more likely to provoke a nuclear world war than are increases in numbers of nuclear warheads. These numbers have been so huge that further increases have had no military or strategic significance.

Very accurate and reliable ballistic missiles are required for nuclear war, and the development of these weapons is the most dangerous current activity in military R&D.

For many years now, a large fraction—probably more than a half—of strategic nuclear warheads has been aimed at military targets even though these may usually have been large-area targets, often in or near cities. But with more accurate warheads, smaller (and, therefore, many more) military objectives can be targeted.

Even though many strategic nuclear weapons have been aimed at military targets, official policy, at least in the United States, was based on 'mutual assured destruction', in which the enemy's cities were the hostages. The theory was that the enemy would not attack if his cities and industry could be destroyed in retaliation. Moves to a nuclear-war strategy are being made not because the requirements of nuclear deterrence have changed (the psychology of the enemy is, after all, the same) but because military technology has made counter-force weapons available. Once available, weapons are usually deployed. Public policy then has to be modified so that politicians can justify any changes in deployment.

Soviet nuclear strategy seems always to have emphasized fighting a nuclear war more than that of the United States, even though Soviet missiles are less accurate and reliable than their American counterparts. As the quality of Soviet missiles increases, so will Soviet nuclear-war doctrine probably become more refined. The more the two great powers adapt to doctrines for fighting nuclear war, the greater the probability of a nuclear war will become—because the perception that such a war is 'fightable and winnable' will rapidly gain ground.

Offensive and defensive strategic nuclear-weapon systems may be developed which will make a first strike possible or, in the opinion of some scientists, probable or even inevitable. In this context, first-strike capability does not mean the ability of one side to destroy totally the other side's ability to retaliate. It means that one side perceives that it has the capability of destroying enough of the other side's retaliatory forces so as to limit the casualties and damage it would suffer from a retaliatory strike to an 'acceptable' level for a given political goal. The more reckless the political and military leaders, the higher this level is likely to be.[2]

War from the seas

Effective anti-submarine warfare would greatly increase the danger of a first strike. About one-third of strategic nuclear forces are submarine-borne. Today, submarine-launched ballistic missiles provide the most secure nuclear weapons for deterrence by the concept of mutually assured destruction.

But an enormous effort is being put into research and development in anti-submarine warfare, the most dangerous of all military R&D in so far as the world's security is concerned. Its very magnitude will almost certainly lead, in time, to success. Success here does not necessarily require a technological breakthrough because steady progress in limiting the damage that can be done by hostile strategic nuclear submarines will eventually lead to a situation in which a first strike may be perceived as possible and even desirable. This will be particularly so when land-based intercontinental ballistic missiles become vulnerable to a first strike by the enemy's land-based

strategic missiles. In the not-too-distant future, nuclear strategic submarines may become as vulnerable as land-based intercontinental ballistic missiles.

Current American anti-submarine-warfare techniques could already seriously limit (although not reduce to zero) the damage which could be done by a Soviet strategic nuclear-submarine fleet in a second strike. This fleet is, in any case, relatively disadvantaged by geography. Its exits to the Atlantic and Pacific Oceans are restricted by channels which can be relatively easily monitored by existing anti-submarine warfare equipment. Moreover, although the USSR has about seventy modern strategic nuclear submarines, only six to seven are at sea at any one time.

Even though anti-submarine-warfare weapons are continually evolving, the critical element in this kind of warfare is detection. (The destruction of submarines is relatively easy once they are detected.) Current developments in anti-submarine warfare surveillance include more sensitive sensors, increasing integration between various sensing systems, and improved processing of data from anti-submarine warfare sensors. Airborne, spaceborne, ocean-surface and sea-bottom sensing devices are becoming increasingly complementary and, therefore, more effective. There is also improvement in the integration of anti-submarine warfare aircraft, surface ships and hunter-killer submarines. Because each weapon system has characteristics which complement those of the others, this integration leads to high effectiveness.

When nuclear strategic submarines become vulnerable, the danger of a nuclear world war will be particularly stark. No sane political leader wants a nuclear war. Nevertheless, at the risk of repeating myself, we are being driven inexorably towards it by the sheer momentum of advances in battle technology generated by military R&D.

The public needs to be informed

Ever since the Second World War, great efforts have been made to control military technology, and to stop the nuclear arms race between the United States and the USSR. Many of the world's most brilliant people have been involved in these efforts. No other problem has received so much attention in the United Nations and other international forums. Whole libraries have been written about the need to control military technology and to stop the arms race. Yet, because of the enormous political influence of those groups in the great powers which continually press for the use of all conceivable technological advances for military purposes, there has been virtually no success in this endeavour.

The large number of researchers—mainly, but not only, physical scientists—financed from the military budget is one such group. Vast bureaucracies have grown within the superpowers since the Second World War to deal with military affairs. The military-industrial complex has grown into a military-industrial-bureaucratic-academic complex. The total vested interest in maintaining and increasing the level of military spending is so huge and diverse as to be almost, if not quite, politically irresistible; this investment is probably the major single obstacle to disarmament.

Nuclear and other arms races go on more or less as fast as human skill in the American and Soviet societies allows. Military R&D has been more or less unrestrained by a lack of financial or manpower resources.

The main (if not the only) hope for the future, that I can see, is that the

public will learn the facts in time and an aroused public opinion will force reluctant politicians to stop the arms race and reduce armaments. I am convinced that, if left to themselves, the political leaders will not be able to prevent a nuclear holocaust, even though they may sincerely wish to avoid catastrophe. I am equally convinced that if the public knew the truth about the nuclear arms race, it would insist that the political leaders stopped it. ■

Notes

1. Since their introduction in 1970, about 550 of these missiles have been deployed. Minuteman III is a long-range (11,250 km) strategic ballistic missile with a small (300 m) circular error probability (CEP). The CEP describes the radius of a circle, centred on the target, within which 50 per cent of the projectiles aimed at the target are expected to fall.
2. See, in this respect, J. Hackett et al., *The Third World War*, London, Sedgwick & Jackson, 1978 and B. Esambert, *Le troisième conflit mondial*, Paris, Plon, 1977.

To delve more deeply

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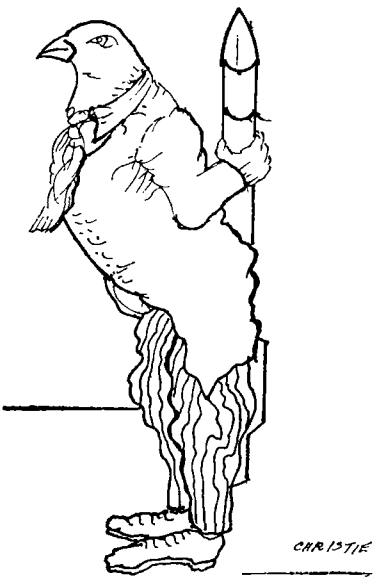
A record of civilian search for military innovation

Rolf E. Glitsch*



Born at Schwabhausen near Munich, the author studied applied geophysics and geology upon completion of his military service during the Second World War. While completing his doctoral work (University of Munich), he worked in Sweden in the exploration of iron ore. Dr Glitsch later engaged in geophysical exploration in the Federal Republic of Germany and Turkey. In 1961 he joined Bonn's Geophysical Advisory Service, where he elaborated military applications of geophysical measurement. Since 1964, he has worked in Unesco units concerned with the application of engineering sciences to the needs of developing countries. Dr Glitsch can be reached at Unesco SC, 7 place de Fontenoy, 75700 Paris, France.

* The author wishes to thank the following for their courteous assistance in the preparation of this article: At the Militärgeschichtliches Forschungsamt, Freiburg im Breisgau, Oberstleutnant Dr Rhohde and his deputy, Major Marwitz; at the Bundesarchive, Koblenz, Dr Oldenhage; and at the Historisches Archiv, Fried. Krupp GmbH, Essen, Messrs Köhne and Müther.

By way of introduction

At the moment of writing, the world faces several crises in which peace is in danger. Earlier negotiations between Egypt and Israel are not developing at the speed anticipated, the Embassy of the United States in Tehran and the illegal holding of diplomatic personnel as hostages continues, and the Soviet intervention in Afghanistan are all threatening situations. The possibility of the outbreak of a third world war, indeed, is more threatening than at any time since the Bay of Pigs crisis in 1961 and the showdown the following year between the United States and the Soviet Union over missiles in Cuba. The two superpowers, the United States with its NATO partners and the USSR with its allies of the Warsaw Pact, are trying to overcome the critical situation without losing face.

Today the Federal Republic of Germany, the largest left-over of the Germany of the Third Reich, is no superpower. Yet it is a leading nation within NATO because of its large industrial potential, and it has an important part to play in world actions to help defuse the current political situation. Furthermore, if one considers the particular development of the Federal Republic of Germany in the years following the last war—consisting of the political brainwashing of its population by the occupying powers, complete demilitarization, and approximately ten years later the reconstruction of its armed forces—it is evident that the Federal Republic is a good example of the relationship which can exist between civil research in science and technology and military applications.

An additional factor to consider is that there are still today a number of people occupying important decision-making posts in both government and industry who participated actively in the Second World War and its prelude; many of these are making direct contributions to helping solve a number of global problems.

Because of these historical developments, Germany, and especially the Federal Republic of Germany, will be referred to frequently in what follows.

Function, form, and even flourishes

Probably for as long as man has existed, there have been wars and a need for arms. During the stone age,[1] man had to make his own weapons in order to hunt so as to survive. The same instruments were used, when required, to fight other men. Archaeological research has shown that special skills developed in the manufacture of hunting weapons, depending on the characteristics of the hunter's habitat. These tools were even modified in some cases for use in battling other groups of human beings. Indeed, the manufacture of weapons reached the scale where it was no longer possible for an individual to provide himself with the food, clothing and shelter he needed—and to equip himself with the tools needed therefore. As skills and trades became more specialized, the individual often received food, clothing or shelter in kind as payment for work.

With this step towards remuneration for professional skill came man's next move, that of employing 'staff' to enlarge the 'business' and make it increasingly profitable; this is the first evidence of the role business (i.e. successful commerce) has played in the production and distribution of weapons from the beginning of *Homo sapiens*' existence.

As mankind evolved further during the bronze and iron ages, when

specializations proliferated, arms production became further specialized between defensive and offensive devices (including even buildings and settlements whose architecture was based on motives of defence). Until the beginning of the Industrial Revolution, as defensive facilities and weapons became increasingly effective, the design of arms and fortifications grew not only in their efficiency but in their aesthetic appearance.[2] In earliest times, designs made on a stone axe were intended to impute strength and power to the warrior wielding it. Later, as the functional design of weapons improved (whether for attack or defence), their constructors artfully added designs and flourishes using expensive materials such as jewels and fine fabrics. The same applied to military architecture (castles) and entire settlements (fortified farms, religious sites and towns), where every effort was usually made to combine defensive requirements with attractive craftsmanship. It was in fact during the Middle Ages of Europe, China and Japan, as well as during the flowering of Islam, that the most aesthetic merging of function and form was achieved in the design of weapons and fortified installations.

Beginnings of the military-industrial complex

Very often, partnership between the skilled producer of artefacts and the artist developed to the benefit of both so that the two could command correspondingly higher prices for their work. A close relationship became evident between the functional (in our case, military) side and the artistic (civilian) side of such partnership. A combination of skills sometimes existed in one person. Leonardo da Vinci, best known for his masterpieces of graphic and plactic arts, also designed weapon systems far ahead of their time, in addition to defensive facilities for entire communities. (Today, we have difficulty in sorting the civil from the military architecture of the late Middle Ages and the Renaissance in Europe.)

Thus we see that, at least as early as 500–1,000 years ago, there was a linkage between military and civil requirements in the design and fabrication of the products and structures required by man—a linkage that existed well before the advent of the Industrial Revolution. The linkage has changed only as the basic civil and military needs themselves have evolved.

As science and technology advanced with the progress of the Industrial Revolution, various trades and manufactures concentrated on the development of increasingly 'better' weapons. The milling machine, today a basic machine-tool throughout mechanical industry, was born from the need of the United States Army for a light and sure hand gun, as the European emigrants swept westward across the continent of North America. That this kind of development was marked especially in Europe is attributable to the growing political rivalry in the late nineteenth century between Great Britain and imperial Germany.

In the case of Germany, the development of the arms industry came in great part from the lobbying undertaken at the imperial court of William II by large industrial enterprises, such as the Krupp firm. The effort by Krupp was stimulated in part by the reach of its national and international holdings and in part by the I.G. (*Interessengemeinschaft*, trust agreement or combine).[3] Krupp[4] and the I.G. group, with their extremely diversified holdings worldwide, became the first 'military-industrial complex', a phenomenon which later proved to have considerable influence in the shaping of the First World War and, in slightly different form, of the Second World War.

Thus with the help of the large, private financial potential of both these corporate complexes, Germany was able to play a substantial role in both world wars, especially since the nation also harboured scientific and technical manpower on a scale probably unknown elsewhere—at least until the late 1930s. Because research activities in universities and governmental institutions such as the Kaiser-Wilhelm-Gesellschaft,[5] had been concentrated in basic research, the activity we call generically R&D today was at that time undertaken mostly by industry or independent innovators.

The military-industrial complex comes of age

At the beginning of the First World War, I.G. was the world's largest industrial enterprise, even larger than John D. Rockefeller's Standard Oil. The corporate group also employed the greatest number of scientists, its pay-roll listing four current or future 'Nobelists'. These were Paul Ehrlich (inventor of salvarsan, used in the treatment of syphilis), Fritz Haber (who gave his name to the process for synthesizing ammonia), Gerhard Domagk (developer of the sulfamides), and Carl Bosch (who synthesized mineral fuel and saltpetre).

The influence of the civil research in the fields of chemistry just indicated on military applications was widespread; it most surely was a contributing factor in the long duration of the First World War.* I.G. recovered very quickly after the Treaty of Versailles and was to play a similar, and perhaps even more important, role for the German Third Reich during the Second World War.

In the case of Haber's research, the original intention was to find a way to convert atmospheric nitrogen into a compound which could be used as fertilizer. The search was stimulated by the supposition that Chilean saltpetre deposits would soon be exhausted, leaving Germany deprived of a basic component of chemical fertilizer. Haber was not aware, however, of the eminent importance that his innovation would have five years later at the outbreak of war in 1914. Saltpetre was not only a critical substance in the manufacture of artificial manure, it played a key role in the manufacture of gunpowder and other explosives.

The chemical synthesis of ammonia invented by Haber was soon elaborated by Bosch into the large-scale industrial 'Haber-Bosch' process. The enormous expansion of the German saltpetre industry under Bosch's leadership at the beginning of the first universal conflict finds comparison only in the large American plutonium plants constructed during the Second World War to manufacture atomic bombs—the once secret Manhattan Project.

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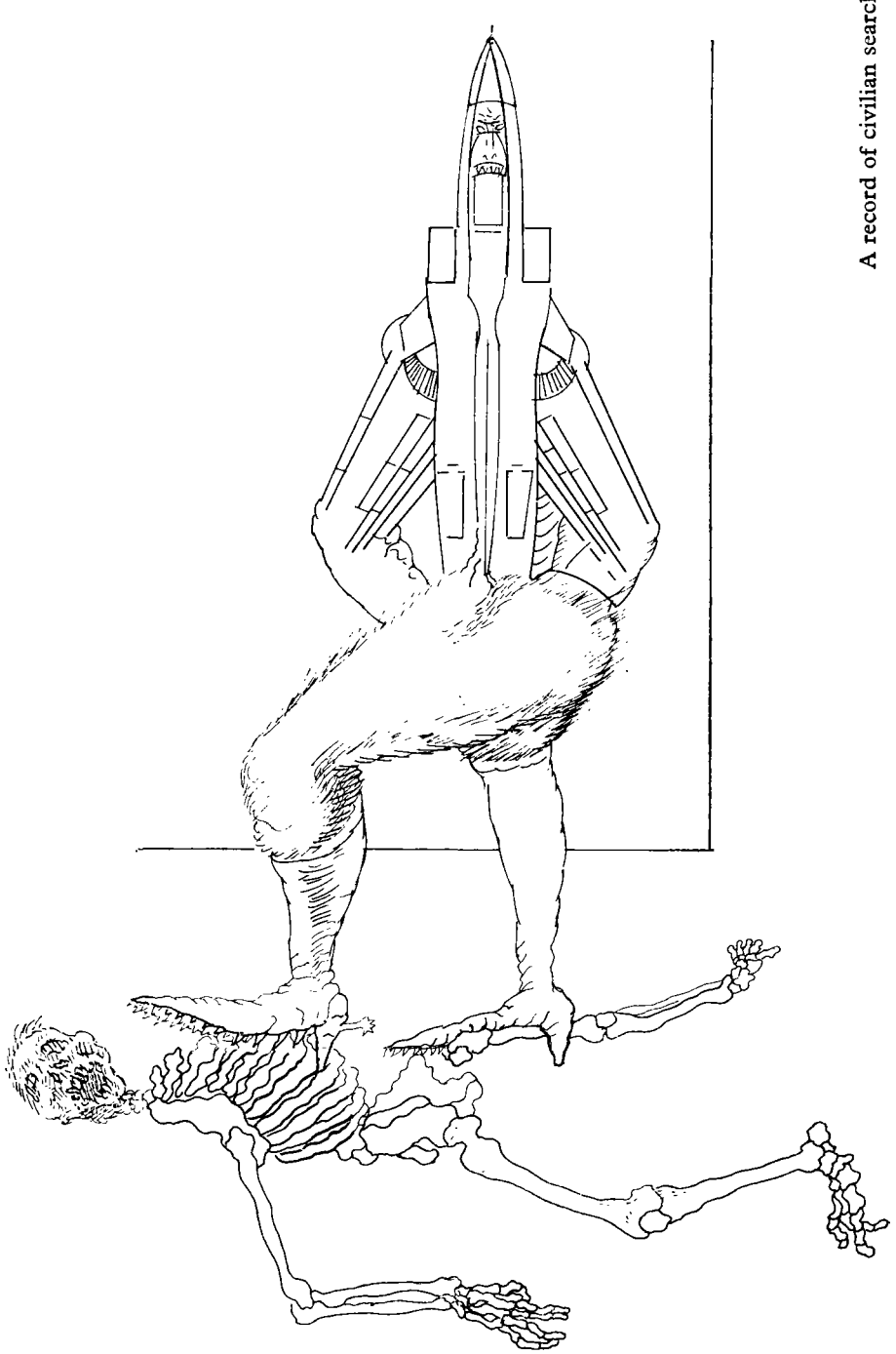
* It has been estimated that statistically during the 'Hell of Verdun', a gigantic battle of attrition fought in eastern France in 1916, at least one high-explosive, percussion, illuminating or smoke-generating projectile fell on each square millimetre of the vast site of butchery. More than 900,000 French and German troops were killed, wounded, taken prisoner or counted missing in the eleven-month engagement. The campaign had no strategic objectives in the concrete sense; the action was meant to abrade the opponent. The French, first the defenders and finally the attackers, lost 72 dead for every 67 Germans killed. A total of 395,000 young Frenchmen and Germans perished.—Ed.

The ultimate reaction of personal conscience among those associated with scientific research intended for peaceful application is exemplified by the suicide of Haber's wife because of his eventual involvement in Germany's gas warfare programme. In 1912, Haber had become director of the Emperor William Institute of Physical Chemistry, part of the Kaiser-Wilhelm-Gesellschaft. He placed the institute at the disposal of his country, concentrating on the potential of toxic gases as weapons—what we now call chemical warfare. This is, indeed, a typical example of the military R&D



capable in civil research institutions possessing the ability to perform fundamental research. We can conclude, with reasonable certainty, that the chemical industry's rapid growth was attributable to the need to assure a constant availability of fertilizer and its military co-products in time of war.

The imperatives of empire

The situation in the iron and steel industry developed somewhat differently. It is generally agreed that the Industrial Revolution began with the steam engine, the ensuing mechanization of significant manufacturing processes, and dispensing with human intervention; the new industrial age increased, in turn, the economic and political power of the British Empire and its drive for colonial resources.

When King William I of Prussia proclaimed himself Emperor of Germany, political circles within the country were determined that the nation would have to grow strong if it was to rival the power of Great Britain. To attain this goal, colonies would be needed and, to safeguard these acquisitions, a large and powerful navy would be required—one preferably as strong as Great Britain's. This was a challenge to both German industry and civil research because the Royal Navy had grown over a period of centuries, while the Germans had only a few decades' experience with a maritime military force. The Krupp interests, closely connected with the court of William I, made use of a unique historical turning-point in order to combine national interest with business acumen. The Krupp combine, through its industrial interconnections, succeeded in gaining contracts to supply nearly everything needed for the rapid buildup, in capital ships and munitions, of the German Imperial Navy.

Much the same situation applied in the case of the ground forces, although it was evident to the Germans that it would be impossible to match the quantity of terrestrial troops available throughout the British Empire and to do this quickly. So quantity was replaced by quality. With few exceptions, German military R&D at the time was available only in manufacturing concerns. So the Krupps scoured the country in order to exploit every available resource, analysing research in progress and adapting it to military use as indicated. In this way, the German armed forces acquired remarkable strength by the beginning of this century, with imperial Germany by then a world power.

Another example of the military exploitation of civil research was the design and building of Krupp's 'Big Bertha' (*Die Dicke Berta*), a giant howitzer named after Frau Berta Krupp. The German Army of 1914 was equipped with a series of these, the most used of which had a bore of 420 mm, and fired projectiles weighing 810–1,160 kg as far as 14.2 km. These field pieces were used early in the First World War to destroy fortifications in Liège and Namur (Belgium), Verdun and Manonviller (France) and Przemyśl (Russian-occupied Poland). The use of such ordnance took the allied armies by surprise, provoking more terror than accuracy of fire.[6]

Later in the war, after the battle lines were stabilized, the German high command resorted once again to psychological warfare, this time against Parisian residents. They ordered the study and construction of an amazing piece of field artillery. The Krupp works proceeded to design a rifle to project a missile of 385 mm a distance of 150 km.[7] '*Die grosse Pariser Kanone*', as this version was called, was mounted on specially built railway cars so

that the enormous gun could be shifted in position at night. (Visual or photographic observation at night was not then practicable.) A special explosive propellant was devised for the 'Big Paris Cannon', and the measurement of the friction developed by its missile as it raced through the bore required new and highly exacting methods.

Because the bore expanded with each firing, succeeding shells had to be manufactured with expanding diameters. Each projectile was numbered, and a total of about a hundred firings took place towards the close of the war. Calculations of changes in diameter had been so accurate that not more than two or three of the specially made missiles had to be discarded. It is astonishing, in retrospect, to realize that problems of material wear and tear had been so well understood during the first two decades of this century that the branch of engineering science we call tribology—the study of friction and the problems to overcome it—was born of the First World War.

Terror, one war later

The idea of combining destruction with horror was followed up by the aircraft builder, Hugo Junkers, a pioneer in civil aviation.[8] In collaboration with Aktie Bolag Flygindustri (Malmö, Sweden), Junkers constructed the first dive-bomber, forerunner of the JU–87 which entered service with the *Luftwaffe* in 1935.[9] Designed much like a bird of prey, this plane—equipped with sirens—loosed its bombs while in an almost vertical dive. The falling bombs inspired veritable terror in their human targets. Comparing their fall with the final curve in the trajectory of a howitzer's missiles, it is evident that the dive-bomber served as a long-range howitzer.

These diving marauders, known generically as *Stuka* (for *Sturzkampfflugzeug*, or diving attack aircraft) were first tested during the Spanish Civil War by Germany's Condor Legion in support of the forces led by General Francisco Franco. Later, during the war of 1939–45, the Luftwaffe made good use of these machines in Poland, the Netherlands and France; the German air arm thus dominated Europe's airspace. But during the Battle of Britian (1940–41) the JU–87 showed its limitations as a rather slow aircraft (maximal speed, 408 km/h at 4,120 m altitude), and it became an easy target for the fighters of the Royal Air Force. Having lost its primacy as a dive-bomber, this type of aircraft was modified and used during the closing years of the war as a weapon against tanks.

I mentioned the birth of tribology as a result of the development of heavy arms technology earlier in the century. There is another interesting chapter in the emergence of this new engineering science. During the First World War, a German artillery officer named Mintrop was preoccupied by the shock waves created at ground level by both guns and projectiles. After the war, Mintrop devised a method to record and measure shock waves, using at first artillery ammunition and later dynamite, in order to determine underground stratigraphy. Using this method of seismical exploration, specialists found the first large oil fields in Texas. The process continues to be used, and it is largely responsible for the wealth of petroleum-rich nations. Who could have imagined, two generations ago when the world's map was quite different, the economic significance of a basic technical innovation attributable to an inquisitive artilleryman?

Brand-new ideas in military technology

With the end of the gruesome conflict and the return to civil life of millions and millions of young men who were the first to know the horrors of modern technological warfare, the pertinence of civil research to military applications became attenuated somewhat. The victorious powers had little taste for military R&D, while the nations that lost the war had to pay heavy reparations in both cash and kind to the winners.

After the political events of 1933 in Germany, the building of a land force of 100,000 men (there was no navy or air arm to speak of) and the mechanization of the army once again prompted military research. The universities, some of them many centuries old, continued to centre their research at the fundamental level, while the university-level institutes of technology or engineering schools preferred applied research. The university had long awarded the doctorate of philosophy[10] as the crowning diploma for excellence in advanced, original scientific research; the technological institute (*technische Hochschule*) had only recently earned the right to confer the same academic degree in applied research.

As the preparations were made in Germany for another world war, all available manpower—particularly specialists—was earmarked for specific needs. It was evident that existing military *matériel* needed improvement, and presently all research undertaken throughout the Third Reich had military overtones. Because of its racial policies, the Hitlerian regime lost considerable scientific potential (about 1,700 university instructors at the level of professor emigrated), but virtually all of the remaining talent was shunted into military R&D. One of the talented individuals was Hermann Oberth, a pioneer of the space age, who in 1917 had developed a rocket fuelled by a mixture of alcohol and oxygen. During the Second World War, working with Wernher von Braun, Oberth's R&D team at Peenemünde refined the V1 and V2 missiles which were used against the Western allies in 1944–45.

Another outstanding German innovator of the time was Willy Messerschmitt, who designed the Luftwaffe's most successful fighter aircraft, the Me–109. He later developed the first successful jet-powered airplane, the all-weather Me–262 fighter-bomber. Besides the innovation represented by the jet engine, Messerschmitt's accomplishment lay in the fact that these aircraft were the first in Germany to be constructed on assembly lines and entirely of metal—a pre-war innovation intended to give global primacy to German civil aviation.

A final technical development made in wartime Germany evolved from a new philosophy adopted concerning sophisticated, high-quality arms of proved effectiveness: this was simplified construction combined with the idea of discarding the weapon after use. A typical example was the recoilless anti-tank grenade launcher known as *Panzerfaust* (fist of armour). With developments of this kind, an important scientific-technical change had taken place in German policy concerning military economics, one approaching that of the mode of arms production in the United States.

Scientists begin to condemn military research

None of this prevented victory by Germany's foes, however, nor the destruction of many cities, towns and villages throughout Europe and in Japan as well as the radioactive contamination of two large urban areas in Japan.

The effects of the relationship between civil research and military application also included ravages among the male population in particular, with demographic consequences; the effects on the attitudes and behaviour of men and women returning home after months or years of imprisonment, often on the fringe of survival; and the impact on the total population of years of postwar occupation by foreign conquerors.

One of the net results of these historical episodes is that many people have lost the taste for war, if one can call it that. They want nothing to do with militarism, armament and aggression. Many specialists in the victorious countries have turned their backs on military research; numerous are those actively engaged in efforts to control armaments, limiting their use in the settlement of disputes, or eliminating weapon systems altogether. Outstanding among these was Albert Einstein who, despite his encouragement of President Franklin D. Roosevelt to have the United States develop a fission bomb, was overcome by his sense of responsibility as a citizen and published—together with Lord Russell, the British mathematician—the Russell–Einstein Manifesto of 23 December 1954.[11] By this manifesto, the two scientists wished to make a concrete move in urging nuclear disarmament.

That the problem of disarmament was of serious concern to scientists at the time is reflected more generally in the Mainau Manifesto, which was prepared, at the instigation of the chemist Otto Hahn during the annual meeting of Nobel Prize winners held at Mainau on Lake Constance.[12] The date of the manifesto is 15 July 1955; it is signed by eighteen Nobel laureates. Within another three years, the Pugwash conferences on science and public affairs had been formed, whose participants now include researchers from many countries, East and West, North and South.

There is still another element to be evoked when one speaks of the evolution of the relationship between civil research and its possible military applications. This is the fact that research is no longer unidisciplinary, it has become transformed into 'big science', and therefore usually costs much money. Transdisciplinarity is now a way of life in research and, in the German university system, signifies a revolution. Personal credit for the acceptance in German universities of a multidisciplinary approach to solving scientific problems goes to Rudolph Mössbauer (Nobel Prize in physics, 1961). In fact, the new academic organization of German universities is sometimes called the 'second Mössbauer effect'.[13]

The nature of military R&D today

Although I have described certain changes in the research process in the Federal Republic of Germany, a similar evolution has occurred the world over. Scientific problems occurring in military R&D are in many cases of such a complex and interdisciplinary nature that they are differentiated, and their diverse parts are then assigned to a variety of institutes, foundations and other research bodies. Often these 'orders for research' are modified somewhat in order that they can fit into the basic research programme of the institution approached. The scientist or technician working on a narrow, highly specialized aspect of a given problem is often unaware that his work might have potential in military R&D; the funding for such research appears to originate in a civil body of some sort.

It should be added that it is more and more difficult to make the distinction between what is civil and what is military R&D. There is a vast grey

zone between the two that permits research to be used for the benefit of military as well as civil needs.

There is still another factor, this one much more abstract, lying among the various motives for research. This involves human behaviour and the emphasis on prestige. When the United States Congress approved the costly Apollo programme, the idea that the Americans could be the first to set foot on the moon was something that a parliamentarian could easily explain to his constituents and from whom he could expect votes at the next election. Had the parliamentarian suggested that the same amount of public money be spent on, let us say, cancer research, the prestige accruing to the nation might have been construed as less significant—possibly putting into jeopardy the legislator's re-election.

Unbalanced military spending and the road ahead

Thinking in terms of national prestige projects, which often have built-in military aspects, is to be found in developing countries as well as among industrialized nations. There, prestige is of particular importance because many of these countries are rather newly independent, and some of them spend disproportionately large fractions of the national budget on armaments. How justified it is for this or that country to build its defences is hard to say but, if all nations would join a disarmament movement with equal eagerness, then not only would the arms race come to a halt; civil R&D would become an activity responding to mankind's material needs as well as to the satisfaction of our natural curiosity about the universe around us.

The findings of the Independent Commission on International Development Issues, headed by Willy Brandt, elaborates this undesirable situation. The commission's report, *North–South: A Programme for Survival*,[14] also reveals that countries having a free-market economy are spending less on arms and giving more aid to the developing world than countries with a centrally planned economy. The free-market economies' relationship of foreign aid/military costs is 1 : 4, while the comparable ratio for the centrally planned economies is 1 : 9. In other words, the centrally planned states are spending more than twice what the others spend on military budgets; and they give less than half in foreign aid than the free-market states.

I have tried to review the relationship between civil research and military development from earliest times. It has become evident that money and business are closely related to the subject of this article. It is pleasant to dream that perhaps one day all peoples will be able to elect their lawmakers and choose their decision-makers in such a way that business and money would be used only peacefully, to mankind's greatest benefit—both in 'developing' and in 'developed' countries.

Meanwhile, one can continue to hope that research results in the civil sector will be used diminishingly for their military value. We have a long way to go along this road, but it is a way which can and must be followed. ■

Notes

1. In referring to the stone, bronze, iron and industrial ages, we cite periods in the evolution of man rather than precise periods in the history of the earth because different cultures passed through these ages at various times counted in years.

2. See frontispiece of *Impact of Science on Society*, Vol. 26, No. 1/2, 1976.
3. The original I.G. was a combine of the largest chemical companies in Germany: Bayer-Leverkusen, Farbwerke Hoechst, Badische Anilin und Soda Fabrik (BASF) and some smaller but important firms such as Agfa. I.G. was better known between the wars as I.G. Farben. Cf. J. Borkin, *Die unheilige Allianz der I.G. Farben*, Frankfurt and New York, Campus Verlag, 1977; *Der Spiegel*, 4 February 1980.
4. H. Hempel, T. Heuss and B. Reifenberg (eds.), *Die Grossen Deutschen*, Vol. 3, Ullstein-Berlin, Propyläen Verlag, 1956/57.
5. Contemporarily, the Max-Planck-Institut.
6. R. Lusar, *Riesengeschütze und schwere Brummer einst und jetzt*, Munich, J. F. Lehmann Verlag, 1972.
7. As a boy, I had at home a copy of the book, *Wir schossen nach Paris* (We Fired at Paris), which disappeared with my home in an air raid during the Second World War. I have not been able to find a second copy in order to verify the figures concerning the large, rifle-type guns aimed at Paris but I am confident that they are of the right orders of magnitude.
8. H. Hempel, et al., op. cit., Vol. 5, p. 422.
9. K. Munson, *Die Weltkrieg II Flugzeuge* (4th ed.), Stuttgart, Motorbuch Verlag, 1977; *Aircraft of World War II*, London, Ian Allan, 1972.
10. The degree of doctor of philosophy originally was awarded to successful candidates in the university's department of philosophy—to which belonged the natural sciences. As specialization grew, it became the custom to award the Ph.D. to linguists, historians and archaeologists as well as to philosophers and chemists.
11. See *Impact of Science on Society*, Vol. 26, No. 1/2, 1976, p. 15.
12. *Mainauer Kundgebung*, Mainau/Bodensee, 15 July 1955. See also H. Armin, *Die neue Physik: Der Weg in das Atomzeitalter*, p. 109, Munich, Verlagsgesellschaft Gräfelfing vor München, 1968.
13. H. Armin (ed.), *German Nobel Prizewinners*, p. 109, Munich, Verlagsgesellschaft Gräfeling vor München, 1968.
14. *North–South: A Programme for Survival* (with an introduction by W. Brandt), London and Sydney, Pan Books, 1980.

INTERSCIENTIA 81

Scientific film forum

Italian Radio-television and the Italian Scientific Film Association are organizing, under the patronage of the International Scientific Film Association, the third meeting of Interscientia—an international forum for the screening and discussion of televised European science programmes and of scientific films available to television producers.

The meeting will take place in Milan in April 1981, in the setting of the International Film and Television Market (MIFED). For further information concerning this meeting, contact the Association Internationale du Cinéma Scientifique, 38 avenue des Ternes, 75017 Paris (France). Tel: 572.10.40 and 574.68.64.

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It should be recognized, as a law of nations, that the right of a state to possess armed force is not unlimited. Restrictions should be based on the recognized, legitimate use of armed power—only to neutralize aggression by other states. To this end, small nations should become increasingly engaged in the arena of arms control and disarmament.

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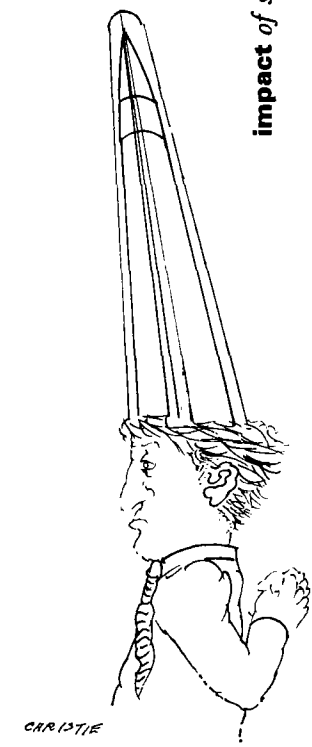
Arms control, disarmament and small countries

Bert V. A. Röling



Professor Röling received the doctorate of laws from the University of Utrecht in 1933. He has served as a judge in both Utrecht and Middelburg in his native Netherlands, at the International Military Tribunal for the Far East (1946–48), and on the Supreme Court of Cassation (1950–53). He has been professor of criminal law and criminology at the University of Groningen. The author of three books and numerous articles, he later served as professor of international law and polemology and director of the University of Groningen's Polemological Institute. From 1950 until 1957, the author was a member of the Netherlands delegation to the United Nations. He is a co-founder of the International Peace Research Association and a member of the Governing Board of the Stockholm International Peace Research Institute since its founding. Address: Polemologisch Institut R.G., Rijkestraatweg 76, Groningen, Netherlands.

Weapons as guarantors of place

Probably no period in history has lacked moral protests against war. As far as I know, such protests have never been effective. Comparing the strife for peace in the pre-war and post-war periods, the great difference is that at present a 'rational pacifism' exists next to the 'emotional pacifism' of lore. It is no longer only a question of goodwill, but rather a question of good sense, not only a question of moralism but rather of rationalism, reasonableness. Peace research, the science of war and peace—this typical feature of the atomic age—wants more clarification about the effects of war as well as of the factors leading to war. The purpose is to find ways and means to prevent military confrontation that might lead to the destruction of our civilization. It appeals to the long-term self-interest of states. Its 'cost-benefit analysis' leads to rational arguments in favour of direct, concrete sacrifices (for instance in national sovereignty, in economic well-being, even morally and legally) for the sake of the abstract and far-away interest of avoiding war. It is evident that technological innovation in weapons (nuclear weapons, missiles) was the main reason for this new approach. It became clear that the available means of mass destruction had not changed the traditional conduct of states.

In the nineteenth century, expectations were quite different. A school of thought existed which was convinced that the destructiveness of weapons would bring an end to the war system. It did not have trust in the religious and moralist movements against war: it put its confidence in weapon development.

Apparently the positive attitude towards technology, typical of the last century, contributed to the opinion that technics would bring not only wealth, but also peace. Dmitri Mendeleev considered the perfection of arms and the study of explosives 'the best and surest means of reaching general peace'. Louis Pasteur wrote: 'A day will come when war will kill itself thanks to the progress of science, which will lead to devastations of such magnitude that every conflict will become impossible.' At the Second General Peace Conference (Paris, 1849, under the chairmanship of Victor Hugo), a participant who wanted 'to give a more practical character to the deliberations', proposed: 'A premium shall be awarded to the inventor of the most powerful and rapid means of destruction.' The Wright brothers sincerely believed that their invention would make future wars practically impossible; they received a medal from the French Peace Society. Alfred Nobel, inventor of many new means of warfare, wrote in 1892 to Bertha von Suttner (the author of *Die Waffen nieder*):

> Perhaps my factories will put an end to war even sooner than your congresses; on the day when two army corps may mutually annihilate each other in a second, probably all civilized nations will recoil with horror and disband their troops.

Later, Nobel realized that his weapons still were not destructive enough.

> To remedy this defect war must be made as death-dealing to the civil population at home as to the troops at the front. Let a sword of Damocles hang over every head, and you will witness a miracle—all war will stop instantly, if the weapon is bacteriology.[1]

Man's faculty of predicting the future appears to be rather limited. We have reached the stage where existing arms can destroy the world's population many times over. But the maintenance of peace is not ensured. Weapons are not abolished (though a treaty has been concluded prohibiting the possession of bacteriological weapons). States possessing new weapons of mass destruction may have become a bit more careful in their relations, a bit more prudent; they have concluded treaties by which it is forbidden to launch war (Article 2, subparagraph 4, of the United Nations Charter)—that is, to start a premeditated war, war as a means of national policy—as well as treaties to prevent accidental or inadvertent wars, feared by all but occurring as a road accident in risky international traffic. Our world still lives in fear of both kinds of war.

The weapon dilemma

Weapons of mass destruction exist, the atomic weapons. If the available nuclear-weapon arsenals would be used by the two military alliances, NATO and the Warsaw Pact, the parties would destroy one another. The whole of mankind could fall in jeopardy because of the long-lasting consequences of radiation. The risk that any war between 'East' and 'West' could end in total nuclear war is so great that war between them can no longer be regarded as *ultima ratio*. This function might seem still to exist between Third World countries. It has been suggested, therefore, that war has become the privilege of the poor and underdeveloped. But conflicts within the 'South', or between 'North' and 'South' countries could fall into the controversy between East and West. Third World crises gain additional impact from the fact that they can reinforce traditional East–West rivalries and security concerns.

For states possessing nuclear weapons, one must conclude that their armed power has become too destructive for use among themselves; their weapons have become too effective. This over-effectiveness has made the weapon systems unusable. Defence against these weapons is impossible. Military and political experts came rather early to the conclusion that defence with nuclear weapons would lead to the destruction of the lives, values and goods that were to be defended.

So the present weapons of mass destruction have become unusable in battle. Should this lead to their one-sided abolition? In case one party should disarm unilaterally, the weapons of the other would become usable again. It could again use its weapons without fear of retaliation. Consequently, weapons may have become unusable, but they are still indispensable. As long as we do not arrive at general disarmament—till now, all endeavours to achieve effective arms control and disarmament have failed—a state needs armed power to keep the weapons of his opponent unusable.

The function of military power

The question then is: What is the reasonable function of national armed power when such armed power is unusable but still indispensable? The question is also: Which military functions are indispensable and which functions might be eliminated without danger to peace and security?

Considering the functions of military power, a distinction should be made between these functions that aim at the extension of power—one might

call these the acquisitive functions—and those aimed at the preservation of existing power and interests—one might call these the defensive negating functions.

The clearest type of acquisitive function is the use of armed force for conquest, the aggressive war. A second type is the more hidden form, where the threat is used to gain concessions. Schelling spoke of 'coercive diplomacy', in which 'the power to hurt' is used as bargaining tool. 'To exploit it is diplomacy, vicious diplomacy, but diplomacy'.[2] Others prefer the term 'indirect or oblique use of military power' or 'potential use of military power'. Distinction should be made here between threats to gain advantages and threats to prevent harmful action by the adversary. The latter action belongs to the negating functions. A third acquisitive function can be seen in the doctrine of 'total strategy' as developed by the French general, André Beaufre. Beaufre was aware that, in the atomic age, military power should no longer be used directly for making conquests. Liberty of action existed only in other fields, those of economy and ideology. Through these indirect ways, conquests could still be made—for example, by assisting in a changing of regime. Military power would thus still have a role; to prevent, by deterrence, the military retaking of that which was lost by non-violent aggressive action.[3]

If it is true that modern technology has made current weapons unusable, then the only conclusion is that armed power should no longer be considered to have acquisitive functions: the risks would be too high. The only reasonable function of arms is the negating one, in the first place the function of deterring armed action by an opponent. This would include the deterrence of coercive diplomacy. A threat to use force would be considered the menace of a paper tiger, should execution of the threat mean mutual destruction. Here we have, for the time being, a clearly indispensable function of national military power.

More controversial is the question whether military might should have the function of deterring harmful acts in the political, ideological or economic field. Is it an indispensable function of military power to forestall indirect aggression? Especially in the economic field, this question has relevance for the United States, Western Europe and Japan. These countries become more and more aware that they are dependent on foreign supplies of raw materials, such as petroleum. They regard regular supplies as a vital national interest; they consider a cut-off as touching upon their very security.

With respect to the concept of security, no doubt exists that different states have different opinions. Small nations may feel secure if there is, for the time being, no question of a threat of direct attack on their territories. Great and strong nations 'will often be concerned with what they deem threats to their security that are more distant in space, time and even in conception than simply direct attack upon their home territories'.[4] Security is an expansible notion, in that it is strongly related to the amount of power available. Thus the greater the power, the wider and more encompassing the concept of security.

> A nation's feeling of insecurity expands directly in relation to its power. The larger and more powerful a nation is, the more its leaders, élites and often its population increase their level of aspirations in international affairs.[5]

The concept of economic security

In the United States, the tendency is apparent to counter with armed force violations of its interests by economic measures. This is clearly indicated in President Carter's speech of 17 March 1978, in which 'American security' was discussed, and 'an adequate supply of oil' was mentioned as one of the bases of national security. This was the speech in which he announced the establishment of 'quickly deployable forces to defend our interests throughout the world'. In Carter's State of the Union address, 23 January 1980, it was said, 'Our excessive dependence on foreign oil is a clear and present danger to our nation's security.' Secretary of Defence Harold Brown's annual report for the 1981 fiscal year was in the same vein, elaborating the concept of a 'rapid deployment force'. Economic security indicates a willingness to react, with military means, if this security is endangered. In the USSR, the concept of ideological security plays an identical role. The Soviet Union is confronted with ideological challenges, such as the Muslim revival, which threaten its spheres of influence if not its internal cohesion. Witness the military action in Afghanistan to prevent the loss of existing influence.

Economic interdependence, including dependence on raw materials from Third World countries, will become increasingly important. Scarcity might lead to internal troubles in case rich countries must adapt to the new circumstances; this could lead to alliance difficulties, should specific states try to obtain preferential treatment. This could lead to East–West conflicts, were armed power to be used to ensure the supply of sufficient materials.

It cannot be denied that a powerful state might extend its privileged economic position for some time by the threat to use military force. In this respect, I would disagree with the opinion that scarcity of goods belongs to a group of threats with which military force cannot cope. But this means gambling, with much at stake, which implies a foreign policy willing to take enormous risks, including that of a world war; one of the superpowers might not be willing to tolerate the other's use of armed force. Such a foreign policy needs overwhelmingly powerful weapons, with global application; such foreign policy is incompatible with disarmament; it means, instead, continuation of the arms race between existing military blocs. A policy of this kind could offer strong reasons to smaller countries to arm, and even to 'go nuclear'. Nuclear weapons have a nuisance value which, especially in cases of economic conflict, might have considerable protective impact.

The growing willingness to use armed force in the service of economic security is making our world an ever more dangerous place. It increases the probability of local wars in the Third World, and the possibility of a world war if the East–West controversy were to affect the North–South relationship in the struggle for spheres of influence. The short-term advantages resulting from the incidental use of force are insignificant compared with the dangers involved in the longer run. Correctly, the Brandt report states: 'If major powers have the illusion that access to raw materials can be settled by military means as a last resort, North–South relations will become a major factor in international tensions.'[6]

The legal prohibition of the use of force

It should be stressed that such a policy would imply total rejection of the principles and rules of the United Nations Charter. The ban on the use of force, formulated in Article 2 of the Charter, loses meaning if every state is allowed to use armed force when it is convinced that its vital economic interests are in danger. According to the Charter, the use of national armed force in self-defence is allowed only in case of armed attack and, even in this case, only so long as the Security Council has not been able to take effective measures (Article 51). The stand of the Charter amounts to prohibition of the first use of military power. This attitude is clearly reaffirmed in the definition of aggression, adopted on 14 December 1974 by the General Assembly (Resolution 3314, XXIX). In this definition, it is expressly stated, 'No consideration of whatever nature, whether political, economic, military or otherwise, may serve as a justification of aggression' (Article V).

It cannot be denied that this strict interpretation of Articles 2 and 51 of the Charter is rejected by many specialists of great authority. One of Julius Stone's main legal arguments against the 'extreme view' is:

> Article 2 (4) does *not* forbid 'the threat or use of force' *simpliciter*; it forbids it only when directed 'against the territorial integrity or political independence of any state, or in any manner inconsistent with the purposes of the United Nations'.[7]

But, from the history of the deliberations, it follows that the addition was considered a stronger pledge than the more conventional promise not to resort to violent means for the settlement of disputes.

The main argument against what Stone later called 'the vulgar view' is the principle of self-preservation, one supposed to override all provisions of international law. The argument is that economic actions may be as devastating to a state's interests, and may be as damaging to its independence as armed action.

It is this threat of the misuse of economic power that plays a dominant role with respect to the present-day function of military power.

The opinion that Article 51 of the United Nation Charter is only one case of legitimate armed self-defence disregards the fact that modern technology has made weapons unusable. Stone's legal theory rests —and in this respect it is in conformity with the practice of states—on the assumption that armed power can still be used in battle for political purposes.

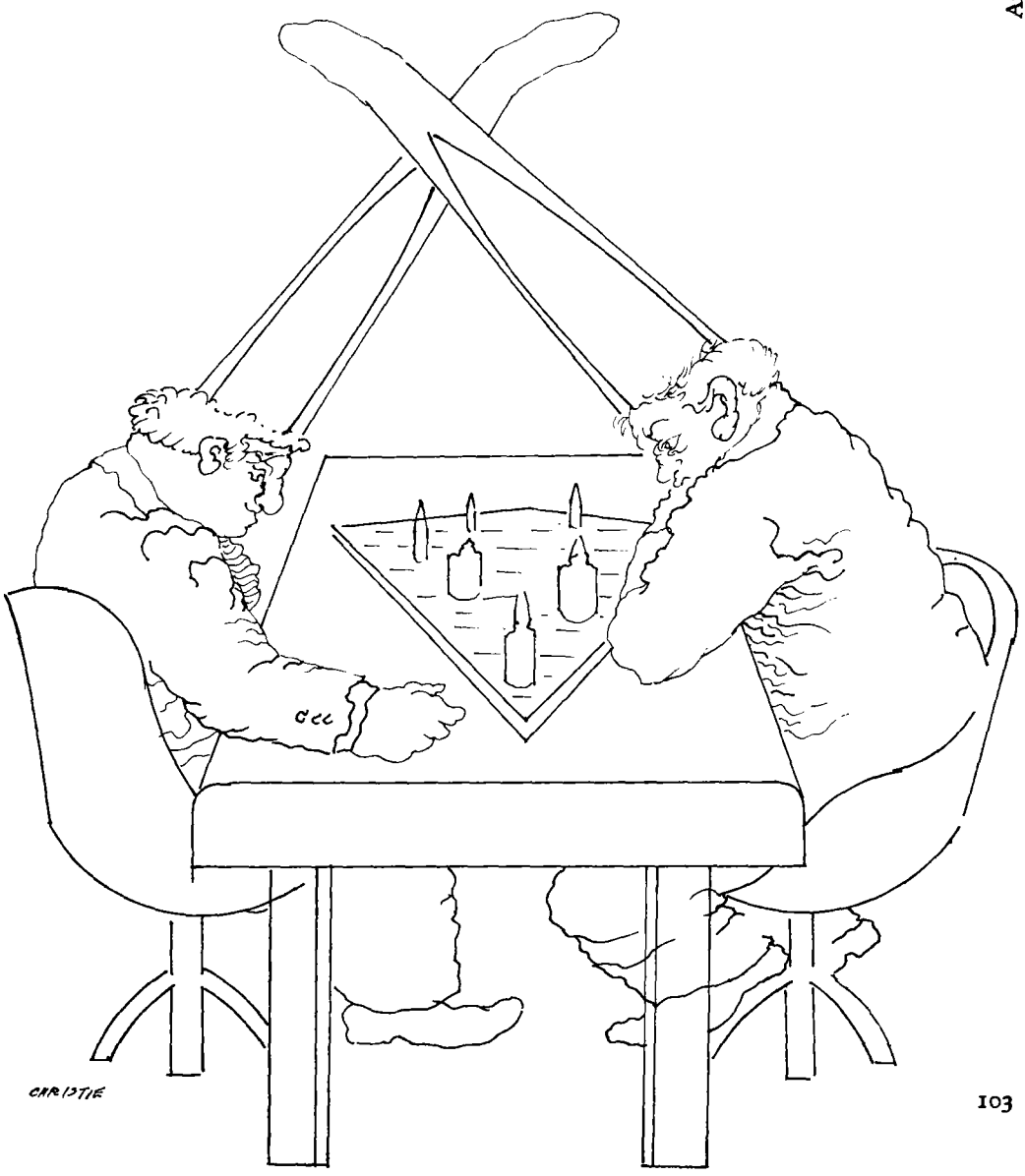
To rely on law in arguments concerning international relations is at best a precarious business. Law is but one of the factors playing a role in deciding the actions in international affairs; it is not the strongest factor. But with respect to the prohibition of the use of force, one should not forget that on the validity of this rule rests the fate of our culture—if not of humanity. The rule prohibiting the use of force, this ground rule of the United Nations system, is not a luxury, making life quiet and pleasant. It is the pre-condition of life itself. It is a law which the world community needs badly if it wants to prevent disaster. It is a law following logically from the facts of life; it is a rule which follows from the present weapon dilemma—that our weapons are unusable but still indispensable. The prohibition of the first use of force is the logical consequence of this dilemma, and it is in our common, primordial interest that this rule be observed.

The legal prohibition of the use of force is not an absolute guarantee

of peace, hence the conclusion that (for the time being) national armed power is indispensable. Hence, too, the view that the sovereign state is entitled to possess armed power, the function of which is to neutralize the armed force of possible opponents, that is, to provide 'military security'.

Military security, weapon security

The decision to restrict the function of their arms to guarantee military security—that is, neutralizing the military power of a possible opponent—is a political decision that governments take. It is a decision of great significance; its effects are felt in many fields, even in peacetime, by every citizen. It means a reversal of the habits of former times, when gunboat diplomacy was effective. Such decision means a fundamental change in the power position of poor developing nations. The freedom of action of these will be extended, e.g. with respect to their national resources, if they no longer have to fear military intervention. This restriction of the military function



is needed if war is to be prevented because of its destructive power. Public opinion must be made aware of the need to arrive at such a political decision, and mass action may be needed to persuade governments to take such a decision.

If the security concept is restricted to military security, the main question is: 'How much is enough?' The military establishments of superpowers are included to demand maximal deterrence, 'such a military posture that one can win if the war has broken out'. They are inclined to strive for superiority, notwithstanding the acceptance of parity as the starting-point in the relations between East and West, between the Warsaw Pact and NATO. This parity was recognized in the SALT I agreements, but still President Carter has declared, 'I am determined that the United States will remain the strongest of all nations. . . .' Soviet statements in this respect are perhaps less blunt, but Marshal Sokolvskiy's treatise on Soviet military strategy does not take an essentially different point of view.[8]

Striving for superiority, especially through the introduction of new types of weapons—technology is the disturbing and destabilizing factor in the military relations of the superpowers—means a continuing arms race, an unwillingness to arrive at disarmament, a gradual militarization of the whole world. It is the road to disaster.

Another approach is feasible in which the question 'How much is enough?' is answered with the statement, 'So much that the other would not dare to attack'. Deterrence of attack can be achieved with fewer weapons than are needed for assuring victory in case of combat. Deterrence takes place if the foreseeable costs of military action are in clear disproportion with the foreseeable gains.

Stabilization (or not) of weapon systems

A state (or a military alliance) whose military philosophy restricts the function of military power to the neutralization of the military power of the adversary should show such restricted function by its choice of arms, its weapon posture, its logistics. If its purpose is what might be called defensive or non-offensive deterrence, then the force should be formidable if attacked but utterly incapable of effective aggressive action outside its territory. What is needed for an effective deterring force is less than, and different from, a military power built up for victory—whatever this may mean between nuclear states—in a possible direct military confrontation. Emphasis on defensive weapons would be one feature, avoidance of destabilizing strategic weapons with a counter-force capability another. The effect of the establishment of such a military posture would mean for the first party the maintenance of military security, and for the other party the almost certainty that it would not be attacked. If the alliances were aiming at preventing war, a buildup of military power based on a philosophy of defensive deterrence would be a reasonable contribution to the resolution of the weapon dilemma.

Military security—security with respect to the armed power of a possible opponent—is closely related with, but should be distinguished from weapon security. Military security concerns the threat that a state might misuse its armed power in aggressive action. This danger is translated into fear of 'the Russians', 'the Americans', 'the Chinese', and so on. Weapon security concerns the danger inherent in the arms themselves.

Human nature being what it is, a specific weapon capability might contribute to anxieties, tensions, conflicts and armed actions. Weapon security exists when military postures do not enhance the dangers of war (the occurrence of war or its intensity). Weapon development can cause tension in bilateral relations if a potential adversary is (a) perceived as building up an offensive-weapon posture or (b) considered as aiming at a disarming first-strike capability, that is the capacity to destroy immediately the strategic weapons of the adversary. Weapon developments also may have global effects, stimulating local arms races, proliferating nuclear weapons, and militarization of the entire world.

With respect to weapon security, the concept of stabilizing or destabilizing weapons and weapon systems is of special significance. A given military posture might put a premium on haste. Weapon security in the bilateral relation does not exist if weapons could give reason to pre-emptive attack in time of peace, or to hasty destructions in time of war.

Where the real danger lies

Both kinds of danger, and both kinds of 'security' should be taken into account. Emphasis on military security often leads to armament measures—and to refusal of disarmament measures—in disregard of the negative effects such action or inaction has with respect to weapon security. The almost exclusive attention to the military capabilities of opponents in the cold war, i.e. to the bilateral relation, leads to a disregard of the global weapon danger—the multilateral aspect. The clearest example is the vertical proliferation of atomic weapons, which in the long run will inevitably lead to horizontal proliferation. There are solid reasons to regard weapon danger a greater threat to the world than any other. It means that, next to military security, the menace of weapon security should receive more attention in considering arguments concerning specific arms control and disarmament measures.

Both concepts of security should be related to the two different kinds of war with which we have to reckon. The traditional type of war was defined by Clausewitz as the continuation of politics by military means. He gave a definition of the premeditative war: the planned use of armed power if political aims cannot be reached by peaceful means. Clausewitz's definition may have been correct for his time, a time of slow motion and deliberate steps. In the present world, the definition is no longer sufficient. We have to reckon now with a war that is not desired by any of the parties, one which might even be feared by all participants as the beginning of ultimate disaster. But such a war could happen as the result of a chain of events, through miscalculation or misperception, the escalation of local fighting anywhere in the world, a crisis which could not be kept under control. An inadvertent war would not be a continuation of policy, but rather its breakdown.

If it is absurd to think that either of the two great military alliances would consider waging a premeditated war—it would be absurd to think so, for both parties are aware of the mutual annihilation which might follow—it is also true that the possibility of an accidental war exists. Here lies the real danger.

We have seen that what may be considered necessary for military security may be harmful for weapon security. What may be considered necessary

for the prevention of premeditated war—e.g. the buildup of weapon strength so that the opponent would not dare to attack—may be disastrous in case of an accidental war (one in which the weapons used were introduced not for fighting but for preventing armed conflict). New arms should thus be evaluated with respect to both possibilities.

Ominous developments in deterrence concepts

It is pertinent here to consider recent developments in deterrence theory. With the emergence of atomic weapons, the world arrived at the period of the 'absolute weapon' which, according to Alfred Nobel, would eliminate war. At least between nuclear-weapon states, Nobel's prediction might seem to have come true. Many analysts are convinced that the absence of military confrontation between the two rival alliances can be explained by their common fear of nuclear war.

The first nuclear strategy was formulated at a time when the United States practically had the monopoly of nuclear striking capacity. John Foster Dulles spoke of 'massive retaliation' in case of Soviet aggression. The threat of destruction of cities (it was called 'counter-value strategy' to make it sound less horrible) was a formidable deterrence. The deterrence became mutual at the moment that Soviet missiles made the United States vulnerable too. The two-sided peril became known as the system of 'mutual assured destruction' (MAD). This balance of capabilities could be endangered by technological development leading to a one-sided or two-sided disarming first-strike capability. The agreement of 1972 not to establish an effective anti-ballistic-missile system (SALT I), together with an accepted ceiling on offensive missiles, contributed to continuation of the MAD situation.

But it transpired gradually that use of the 'central systems' (the inter-continental-ballistic-missile systems of the United States and the USSR) would lead to such destruction of both countries,[9] with hundreds of millions of fatalities that no party would risk such a war. The credibility of American 'nuclear assurance' became more and more doubtful. In 1965 Henry Kissinger wrote that 'the enormous risks of nuclear warfare call into question traditional pledges of formal assistance'.[10] In his Brussels speech of September 1979, he was more outspoken when he said, 'we must face the fact that it is absurd in the 1980s to base the strategy of the West on the credibility of the threat of mutual suicide'.[11]

This was nothing new. In the annual Defense Department report for fiscal year 1977, it was indicated that in case of a Soviet counter-force attack against the United States, a reaction 'which concentrated on people and cities would not necessarily be a wise response'. Such a response could be expected only in answer to 'the most barbaric kind of attack'. It follows that an attack against Europe, *a fortiori*, would not be met with weapons belonging to the 'central systems'.

To avoid misunderstanding, this does not mean that the United States would not fight in case of a Soviet attack on Europe. It means only that the 'central systems' are neutralizing each other in such a way that they will be used only in case the other party does the same. Thus they no longer deter war, they deter primarily the use of the central systems.

'Euro-strategic' weapons

Exclusion of the central systems might explain the fact that the prospect of mutual annihilation has almost disappeared from the strategic doctrines. In the 1960s the concept of the unthinkable war still prevailed, in the United States as well as in the USSR. At present, war seems again to be considered 'fightable'. The introduction in the 1950s of tactical nuclear weapons had been the first step in the shift of thinking, from deterrence by the threat of urban destruction ('pure deterrence') to deterrence by the threat of nuclear combat, from the doctrine of 'massive retaliation' to the doctrine of 'flexible response'. With the elimination of the credibility of the threat of strategic weapons, emphasis was laid on nuclear arms as weapons. Restricted or limited war became thinkable again for the United States as well as for the USSR, especially now that this war could be fought in Western and Middle Europe. This meant a decoupling of the superpowers' territories from the fighting in Europe, making sanctuaries of their own homelands.[12]

In accepting war again as fightable, stressing the combat function of nuclear weapons, changing from pure deterrence to 'deterrence with nuclear fighting power', there was a renewal of interest in innovative weapon capabilities. The thought of fighting a war meant also winning that war, hence a growing unwillingness to strive for substantial arms control and disarmament. On the contrary, there was impulsion for the introduction of new weapon systems with better penetration potential and greater precision.

SALT I was based on the concept of stability through vulnerability. Arms control agreements rested on this starting-point, but the new theory of deterrence rejected this. Kissinger, in his Brussels speech, ridiculed the school of thought

> which considered that strategic stability was a military asset, and in which the historically amazing theory developed that vulnerability contributed to peace and invulnerability contributed to the risks of war. . . . It cannot have occurred often in history that it was considered an advantageous military doctrine to make your own country deliberately vulnerable.

Kissinger's Brussels speech served the purpose of convincing his European allies of the need for more and better NATO weapons, especially of the need to accept the deployment in Europe of 'Euro-strategic weapons', nuclear precision weapons exclusively under United States control and management, and capable of reaching inland USSR. Ominous weapons for the USSR, like the SS–20 Soviet missiles, are ominous for Europe; they give the United States the possibility of attacking the Soviet mainland, without fearing retaliation on the United States. Leonid Brezhnev declared in Berlin that if ever these Euro-strategic weapons are used, atomic bombs will explode on the Federal Republic of Germany and other European states. This means that atomic bombs will not fall on the United States, because this would activate the central systems—and no superpower dares to do that.

The need for a new approach

Recent weapon developments could be catastrophic for Europe. These are mentioned here because they reflect the growing divergence of interest in this field between Europe and the United States and the need for the European states, whether or not belonging to one of the military alliances, to stand up

in the defence of their interest. Europe is badly in need of fundamental arms control. It should react to a development in which nuclear war is considered thinkable again—and the arms control issue is going to belong to the domain of the unthinkable.[13]

All these developments are not the only reason why arms control is in trouble. Technological innovations in weapons—such as the Euro-strategic precision weapons—have blurred the traditional distinction in arms categories which were the decisive criterion in arms-control negotiations. Bertram has mentioned 'the erosion of existing weapon categories'.[14] According to his analysis, there are

> three problems that technological change poses for the future of East–West arms control: first, the speed of technological change injects a high degree of ambiguity into restrictions directed primarily at quantitative levels of force, and not only complicates the negotiations but, more important, endangers the political acceptability of their outcome; second, qualitative improvements are often more significant and less verifiable than quantities of weapons, so that arms controllers have to choose between agreements that are fully verifiable but increasingly irrelevant for the control of military potential and agreements that may be relevant but cannot be adequately verified; and, third, the trend of technological change is towards multi-mission weapons which undermines the definitional categories which have, in the practice of East–West negotiations, been a primary 'organizing principle'.

Hence, there is a need for a new approach, one which does not rely primarily on quantitative restrictions of specific categories of weapons. Bertram's solution, next to unilateral restraint, is 'new units of account, missions instead of weapons'. The term 'mission' is used by him to describe specific tasks to which military capabilities can be put. Such missions should be made the primary and explicit focus of agreement.

The new approach suggested by Bertram merits serious consideration. Its principal aim is to ban the ability to launch a pre-emptive first strike. 'An agreement to forgo a surprise attack capability', he adds, 'will not rule out all armoured forces but only those which, through a combination of numbers, performance and deployment seem to offer a serious option for effective and successful aggression.'

Arms control and disarmament: international law

Traditional international law has recognized the unrestricted freedom of the sovereign state to possess armed force. The Treaty of Utrecht, 1713, had accepted the principle of *justum potentiae aequilibrium*. But this political concept never became a principle of law. Sovereignty of the state implied not only the freedom to decide whether the state is entitled to use its arms against another state, but also the freedom to possess the quantities and the qualities of weapons it considers desirable.

Restriction of the national liberty to use armed power gradually developed into positive law in the twentieth century, leading to the ban on the use of force as formulated in Article 2 of the United Nations Charter. Restriction of the freedom to possess armed force began after the Second World War.[15] Possession of biological weapons was prohibited in the Treaty of 1972. The non-nuclear weapon states, parties to the Non-proliferation Treaty (1968) or the Latin American Treaty of Tlatelolco (1969) are forbidden to acquire

and possess nuclear weapons. A party to the Treaty concerning Environment Modification Techniques (1977) is forbidden to deploy techniques by which earthquakes and hurricanes could be used as means of warfare. Other treaties restrict the quantity of specific weapons a party may possess, as SALT I and SALT II. By some treaties it is forbidden to have weapons in specific places (Sea-bed Treaty, 1971; Cosmic Space Treaty, 1967; Antarctica Treaty, 1959).

Consequently, one might say that for states that are parties to such pacts, a certain rule is valid: 'the right of states to possess arms is not unlimited'. But this is not a general rule of international law because not all states are bound by such accords. Moreover, the treaties can be denounced. The question is whether it should not become a general principle of international law, with further specification as to how far the sovereign right to have arms is restricted by generally binding rules.

Until now, the restriction of a nation's freedom to possess weapons has taken place at the periphery—forbidding either quality or quantity of specific arms. The starting-point of negotiations was the acceptance of specific categories of weapons. But technological innovations made this approach difficult, if not futile. Hence the need for a new approach, which does not rely primarily on qualitative or quantitative restriction with respect to specific weapons, but which adopts new units of account: missions or functions of armed power, instead of weapons. 'Missions' or 'functions' describe specific tasks to which capabilities can be put. Such tasks should be made the primary focus of agreement. Some capabilities should be forbidden, as for instance the capability of launching a successful surprise attack or a disarming first strike. As a general rule, a state should not have the right to possess arms capable of performing functions which are forbidden by international law.

If national armed forces have (according to the present law of nations) as principal function to provide for military security, the question is whether it still should be legitimate to possess armed power with capabilities that go beyond this legitimate function. The question should be answered in the negative. The logical consequence of the ban on the use of force, except in case of resistance against an armed attack, is the prohibition to possess weapons with the capacity to go beyond this. This consequence would mean the prohibition of a national military posture able to wage successfully an aggressive war. It might imply prohibition of the introduction of weapons or weapon systems which might lead to a disarming first-strike capability.

Where the weapon freedom of states should end

Binding rules in this respect are needed. One of the four freedoms in Roosevelt's famous State of the Union message (1941) was the freedom from fear. It implied 'a world-wide reduction of armaments to such a point and in such a thorough fashion that no nation will be in a position to commit an act of physical aggression against any neighbour—anywhere in the world'. Sumner Welles clarified the issue by stating that this implied 'the abolition of offensive arms and the limitation and reduction of defensive armaments and of the tools which make the construction of these armaments'.

It is self-evident that such an embracing set of rules can only gradually be established. The process might start with the adoption of general principles for arms-control negotiations, concerning the introduction of new

offensive or destabilizing weapon systems. These principles should then be applied to existing weapon postures. Gradually they may be formulated as rules of law concerning national 'weapon freedom', amounting to the prohibition of the possession of excessive or disproportionate armed force.

As a general rule of the law of nations, there should be recognized that the right of states to possess armed power is not unlimited. Restrictions should be based on the recognized, legitimate use of national armed power: to provide for military security, that is, to neutralize the armed power of other states.

Military security implies weapon security. Consequently, the restrictions should cover destabilizing weapons or weapon systems. As long as the concept of MAD still plays its inevitable role, assured mutual destruction should be reduced to the minimum. The present overkill should come under forbidden armed force.

In view of the inequalities in the world, regional arrangements should be provided for in the legal structure. It is evident that specific legal provisions are needed for the relations between NATO and the Warsaw Pact, or still more specifically for the European theatre.

The proposed new approach consists of developing guiding principles for the arms-control negotiations, which gradually may harden into valid, generally applicable and binding law. Such law would introduce a new chapter in the law of nations. Its rules would not be concerned with the restriction of the legitimate use of national armed force, but with the limitation of the national sovereign state's right to possess armed forces having the capability to perform illegitimate functions. Such restriction would contribute to the observance of the basic rule concerning national armed power: all states shall refrain in their international relations from the threat or use of force.

The historic mission of the smaller powers

A new approach in the field of disarmament has been proposed. Proposals need addressees who can act upon them. In our case, these addressees are the smaller nations. Until now, arms-control negotiations have been dominated by the superpowers. These have failed to fulfil their duties, even their legal duties as expressed in Article VI of the Non-proliferation Treaty. The result of their activity has been futile, and Alva Myrdal is correct in her analysis: the great powers are unwilling to arrive at substantial arms reduction because they want to preserve their superpower position. The smaller nations should take over. The time has come to apply an old battle cry in a new version: 'Nuclear proletarians of the world, unite!' The smaller nations, members of military alliances and non-aligned countries, should co-operate to make the world safe for modern weapon technology. These states should become more active in the sphere of disarmament and arms control. In collective action, they should develop principles and standards to be applied in negotiations.

The General Assembly of the United Nations should outline, in its resolutions, standards and rules of this new chapter of international law concerning the restriction of weapon freedom. These regulations formulated as resolutions are not yet rules of law. The General Assembly does not have legislative power. But, by its resolutions, it can change the political and juridical climate in the world, as it did with respect to colonialism, racial

discrimination, and the market mechanism of the existing international economic order. This change in spiritual climate is a pre-condition for the progressive development of international law. The vast majority of smaller states would be able, even against the resistance of the powerful, to carry through its strongly felt opinion. If united, the weak are powerful.

The Special Disarmament Session was the first sign of the impatience shown by the small states, and of their misgivings with respect to the arms-control practices of the superpowers. It was a demonstration of protest against the failure, if not the misbehaviour, of the states until now responsible for the effectuation of arms control.

Three other features of the Final Document of the Special Disarmament Session should be mentioned. First of all, the recognition that armaments may be incompatible with the principles of the Charter of the United Nations. Section 12 declares this, with respect to the arms race.

Secondly, the document contains in Section 42 a provision by which United Nations members take upon themselves the obligation to respect its objectives and principles, and to make every effort to carry out faithfully the Programme of Action. And in Section 126 the United Nations members solemnly affirm their determination to work for general and complete disarmament.

This Programme of Action provides for the institutions in which the new role of the smaller states can be played. This role has still to be spelled out, but implies giving guidelines that should be observed in arms control negotiations, and gradually preparing the acceptance of new rules restricting the national freedom of weapons. In the field of arms control and disarmament, the General Assembly has to perform the role of a law-creating agency, as it has done in the field of human rights, and as it is in the process of fulfilling with respect to the new international economic order and to the new law of the sea. In all these fields, the progressive development of international law implies a curtailment of national sovereignty. These curtailments are not unrelated. They are interdependent. Restriction of the right to possess arms will be lasting only if, in other fields, national arbitrariness has been eliminated in favour of state behaviour that fits in a structure aiming at the world's peace and welfare. ■

Notes

1. I took these data from the brilliant doctoral thesis of Peter van der Dungen, *Industrial Society and the End of War, The History of an Idea*, University of London, King's College, 1976.
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6. *North-South: A Programme for Survival*, p. 118, the report of the Independent Commission on International Development Issues under the Chairmanship of Willy Brandt, London and Sydney, Pan Books, 1980.
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9. See the Report of the Office for Technology Assessment to the United States Congress: *The Effects of Nuclear War*, Washington, D.C., Government Printing Office, 1979 (in book form: London, Croom Helm, 1980).
10. H. Kissinger (ed.), *Problems of National Security*, New York, Praeger, 1965.
11. H. Kissinger, 'The Future of NATO', *The Washington Quarterly*, Autumn 1979, Vol. II, No. 4, p. 3.
12. A. Myrdal, *The Game of Disarmament*, New York, Pantheon Books, 1976.
13. I may refer in this respect to the excellent paper of Dr Marek Thee, 'The Doctrine of Nuclear Deterrence', prepared for the Unesco study, *Strategic Doctrines and Their Alternatives*.
14. C. Bertram, *The Future of Arms Control: Part II. Arms Control and Technological Change: Elements of a New Approach*, London, International Institute of Strategic Studies, 1978, p. 5. (Adelphi paper, 146.)
15. After the First World War, the Covenant of the League of Nations mentioned general disarmament as a condition of peace (Article 8). The defeated powers were disarmed as a first step to general disarmament (Part V of the Treaty of Versailles). According to the peace treaties after the Second World War, the vanquished were forbidden to possess atomic, biological and chemical weapons.

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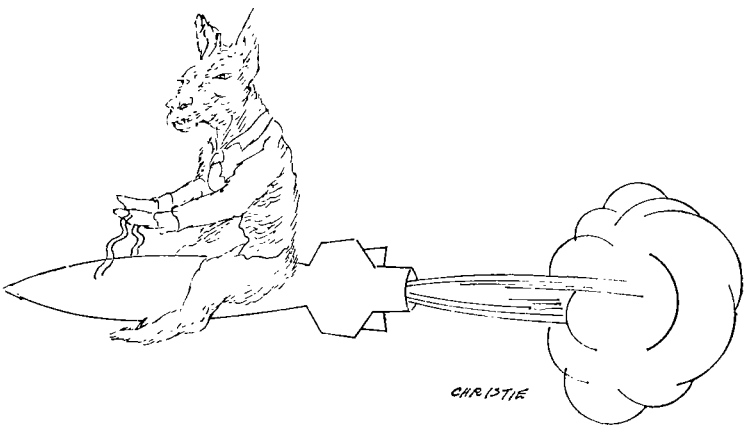
The following discussion and conclusions result from the thirty-fourth Pugwash symposium, held in Avignon, France, in April 1980 to examine the possibilities of establishing an international body to exploit data—for purposes of international security—obtained from satellite observations. Participants came from Brazil, Denmark, Egypt, France, Hungary, India, Israel, Italy, Netherlands, Sweden, Switzerland, the United Kingdom, the United States, and the United Nations.

impact *of science on society*, Vol. 31, No. 1, 1981

Report from a symposium

Using military and civil satellites to keep the peace

Pugwash Conferences on Science and World Affairs



Named after a small coastal community in the province of Nova Scotia, the Pugwash conferences were begun in 1957 under the auspices of the late Cyrus Eaton, a Canadian-American industrialist who was determined to bring together concerned scientists from the world around to discuss openly and without governmental restraints the grave problems posed by modern scientific technology. These concerns are probably best expressed by the Swedish physicist, Hannes Alfvén, who served as Pugwash's president in 1972. He said that the Pugwash group, 'as a union of scientists' is 'alarmed by the fact that science . . . is exploited . . . for destruction and repression'. The accompanying text is one of the many deriving from the long series of workshops, symposia and annual meetings held since the founding of Pugwash almost twenty-four years ago. Further information about Pugwash can be obtained from Dr M. M. Kaplan, secretary-general, 9 Great Russell Mansions, 60 Great Russell Street, London WC1B 3BE, United Kingdom, through whose kindness the report from Avignon is published in this journal.

Introduction

The Pugwash conferences on Science and World Affairs have since 1957 been concerned with the avoidance of nuclear war and with problems of international security. In addition to the scientific and technical components, wherein lie the main Pugwash contribution, such security issues must perforce also involve economic, political, legal, social and military aspects. Furthermore, over and above immediate considerations of keeping the peace, global security issues must also be considered in a larger time frame, in the context of the world of the next few decades—in which arms control and disarmament considerations will be of predominant importance—as well as of the disarmed world of the twenty-first century, towards which we must all strive.

Some time ago, at an earlier Pugwash meeting, the idea was advanced of an international satellite for the purposes of arms control and crisis management. This would be used in conjunction with a global system concerned with the verification of arms-control agreements, the enhancement of confidence among nations, the avoidance of crises and their management in case of breakdowns in international relations. Such a system could be an important component of an international security system.

On the initiative of the French Pugwash Group, an international Pugwash Symposium on 'An International Agency for the Use of Satellite Observation Data for Security Purposes' was convened in Avignon, France, on 14–17 April 1980. At this symposium, thirty-one participants from fourteen countries, meeting in their individual capacities, considered proposals for an International Satellite Monitoring System (henceforth, for the sake of brevity, referred to as ISMOS) such as has been proposed by the French Government.

Regrettably, in spite of attempts at a more universal coverage, the symposium did not succeed in attracting participants from all important regions of the world.

The following is a summary of the most important considerations and ideas discussed at the symposium.

The symposium was timely because of the proposal, made by the President of the French Republic in May 1978 at the Tenth Special Session of the United Nations General Assembly devoted to disarmament, of an International Satellite Monitoring Agency. The proposal envisaged the progressive development of the system in three stages:

ISMOS would receive and process data acquired from states that own and operate such observation satellites.

ISMOS would build and develop its own data collecting and processing facilities.

ISMOS would launch and operate its own satellites.

A resolution requesting the Secretary-General of the United Nations to prepare a study of the implications of this proposal was adopted at the thirty-third regular session of the General Assembly in December 1978 by 121 votes in favour, none against and 18 abstentions.

These developments took place against the background of remarkable progress in the field of space technology and specifically with respect to earth-observation satellites. Observation satellites for both civilian and military purposes have attained a very high level of accuracy and precision.

At present, information from such satellites is collected and processed

by the Union of Soviet Socialist Republics and the United States of America, the two countries with the greatest experience in space technology. It has already played an important role in the verification by 'national technical means' of their bilateral agreements for arms limitation. The potential usefulness of this technology to the international community as a whole is great—in the field of verification of multilateral disarmament agreements, in supporting United Nations peacemaking and peacekeeping efforts and in the field of international crisis management on a local or global basis. It also has great importance in the economic and social fields.

Several other countries now have the capability to operate earth-oriented data-acquisition systems. More countries will acquire this capability within the next five to ten years.

It was therefore considered that Pugwash might make a useful contribution if it were to study the implications of using this technology for the purpose of enhancing international security.

The purpose of this symposium was to study the technical, political, legal and financial implications of an International Satellite Monitoring System (ISMOS).

Technological aspects

The technology is now available for useful satellite-monitoring systems, and it will become available to ever increasing numbers of technologically developed countries in the coming years. The status of this technology, as compiled and summarized by an expert group at the symposium, follows.

Background technology

It is felt that a number of technologies, currently available to Europe, Japan and other industrialized nations without recourse to either superpower, can be integrated into a total information delivery system within reasonably short order—given a guarantee of resources and single-minded management focusing on a defined objective. For purposes of this overview, a development and test period of five to seven years from initiation appears sufficient for the initial deployment of a useful system.

Application to particular methods of observation

The technologies available and deemed applicable to the particular function of international security information acquisition and dissemination fall into several categories:

Panchromatic optical digital imagers with spatial resolutions of some 3 metres or larger can, within bit-rate limitations, afford routine access to pre-selected global areas on a revisit pattern of perhaps four to five days. Daylight scene conditions establish the maximum duty cycle to about 40 per cent.

Infra-red optical sensors, capable of spatial resolution in the 50 metre-or-larger class and of temperature resolutions within ± 1 or 2 K, offer complementary coverage capabilities and can operate usefully at night.

Imaging microwave systems (radar) can provide all-weather day–night scene coverage in the 10-metre spatial-resolution range; limitations of data-rate

management suggest rather low routine duty cycles of the order of 5–15 per cent.

Non-imaging radar used in the altimetry mode as a profile-meter can, over time, build up three-dimensional models of selected terrain areas with good relative accuracy.

Satellite-based ground-sensor interrogation, location, and relay system that continually report to a central station have been proven operationally. Ground sensors can be fixed or mobile, and can be tuned to a wide variety of change detection and environmental reporting tasks.

Trade-offs

In developing any system concept, one must take into account the need to circumvent various inherent limitations by technical trade-off activities. Total observable area may be traded for enhanced resolution by sensor manœuvre and even orbital altitude changes for closer look, if deemed necessary. Images at relatively lower resolution can be used to direct those at much higher resolution from another sensor set, aimed at a smaller area of particular concern.

Applicability to international security enhancement

The sensor types noted above appear competent to provide reasonably unambiguous data on significant facilities of interest, such as airfields, ships, lines of communication, bunkers, or fortified positions and large-weapon test ranges; these represent relatively slowly changing capabilities, and to monitor rates and direction of change appears routinely feasible.

Movement of men and materials can be observed with low ambiguity when traffic is concentrated and directional (rather than subsumed in a normal traffic pattern). Depending on the frequency of observation and the rapidity or magnitude of such movement, the sensor set noted above should be able to provide multiple data sources about such observables.

The existence and location of relatively static forces or material stocks may be observed but probably not measured without significant ambiguities, given normal background clutter and the multi-purpose character of vehicles, buildings and men.

There are many classes of events and items of international security interest that must be classed as *not* observable from space (although circumstantial activities and events may suggest probable purposes): among these are the normal industrial processes carried out in existing indoor facilities, infiltration of men, and the purposes of generally used vehicles or facilities. In addition, it is recognized that countermeasures (camouflage and deceptive actions) can defeat or confuse some of these observation systems.

System concept

To arrive at an operational system concept within available technology limits, space-segment and ground-segment characteristics as well as operational modes have to be taken into account.

Space segment. The combination of the performance of the sensors as described is obtained most efficiently in a three spacecraft system, each

spacecraft carrying one type of sensor, in orbits suitably spaced in plane and altitude. Sensors on board each spacecraft will have a degree of stable angular manoeuvreability and the spacecraft themselves may have limited altitude change capabilities but no change of plane is presently contemplated.

Ground segment. The ground segment of the system is essentially composed of a secure data-acquisition, processing and dissemination centre. The centre comprises the emit/receive antennae, computer facilities with associated archival and retrieval capability, visualization and reproduction equipment as well as communications hardware.

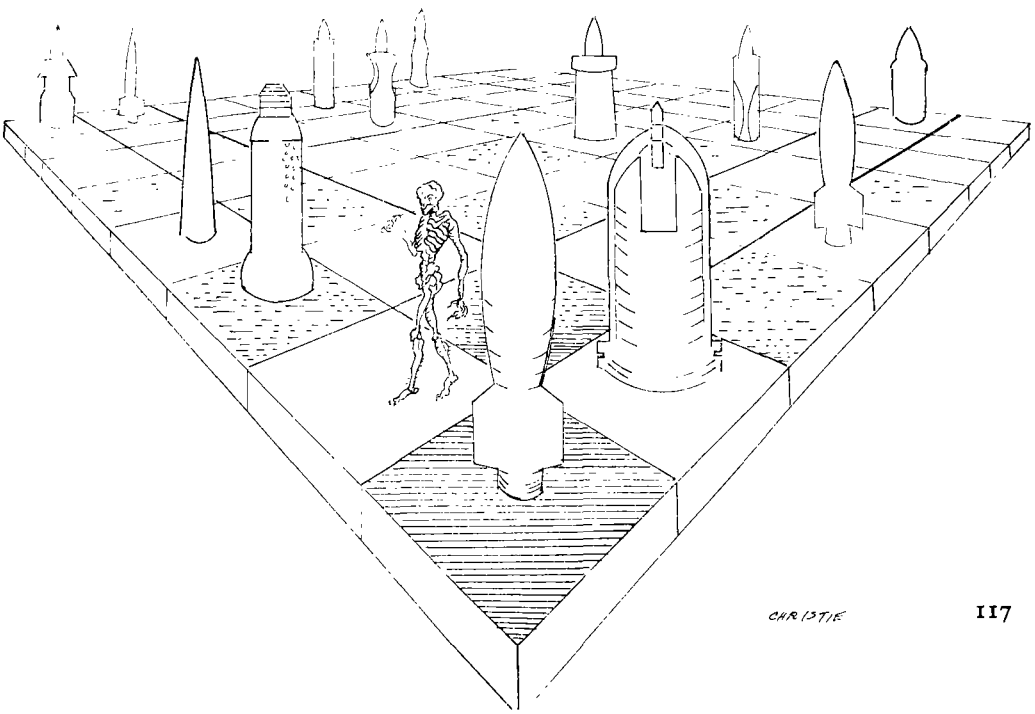
To ensure continuity of operation in a non-cooperative environment where no support from friendly up-and-down-link installations can be expected, mobile data-acquisition and telecommand stations, possibly air-transportable, may be required. In case of inadequacy of data-transmission links, physical delivery (aircraft) may become necessary.

Operational characteristics. The operational activity and procedures will cover essentially three types of situations:

Static conditions. Data acquisition, building up of data banks, routine interpretations, methodological improvements are carried out in a continuous learning process.

Slow-rate-of-change situations. In relation to the situation above data acquisition is focused more precisely on specific zones, retrieval and interpretation activity increases and periodic data format outputs are performed commensurate with the observable rate of change.

Rapidly evolving situations. When one or more rapidly evolving situations are notified, a priority resource allocation status comes into effect. All system elements including the imaging capabilities of the space segment, the up and down links whether fixed or mobile, the relay facilities to and



from the processing centre are activated to enable the date centre to provide, within the shortest practicable time span, the data formats which are appropriate to the situations.

For the system outlined the time span from notification to initial output is estimated to be between two and three days. In the case of most favourable spatial relationship between satellites and zone to be monitored at the moment of notification, this time span can be as small as a few hours. Under worst case conditions the delay in initial output of a meaningful format should not exceed six days.

After initial format output, regular updating and refinement will proceed, following the cycle: acquisition, relaying, recording, preliminary analysis, comparison with previous set of data, conclusions, and progression to the succeeding cycle.

Technical development forecast

In the time span 1990–2000 and beyond, several technical developments can reasonably be expected to occur.

The first category consists of products of R&D programmes not related to ISMOS types of operations and include: overall improvement of IR sensing capabilities (reduction of detector size and improvement of cooling techniques); handling of high to extremely high bit rates and associated on-board storage needs; on-board data compression; improved data-recording techniques (alternative to tape); new techniques for lifting heavy loads to geo-synchronous orbits by slow propulsion from lower orbits.

The second category concerns R&D more directly related to ISMOS types of operation and includes development of machine intelligence for improvement of interactive functions and generation of self-correcting capabilities.

These technical developments allow: (a) improved observation capabilities mentioned above; (b) improved repetition rate of observations, continuous and worldwide monitoring; (c) improved information capability, faster, better and less ambiguous information with integration of information from different sources. The design, development, testing and execution of a new satellite system takes five to seven years.

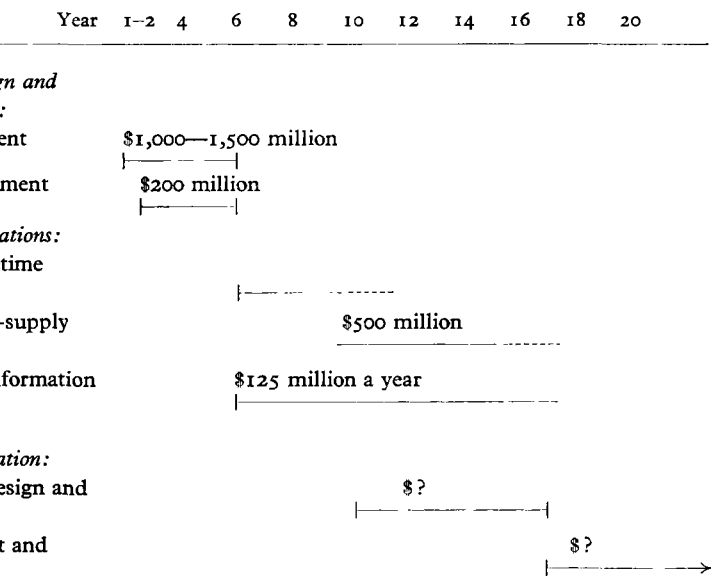
The learning process for a new satellite system and implementation of its full operational capabilities also requires five to seven years, the lifetime of one satellite generation.

ISMOS operations require continuity to serve their objectives. For this reason the second generation of ISMOS satellites should be a duplicate of the first generation with only normal (relatively minor) improvements.

At the time of launching the second generation, around 1990, a decision has to be taken with regard to the development of a third generation. This decision should be based on both the experience gained so far and new technological capabilities, and should include a re-definition of functions and modes of operation of the system.

At this stage a study could be made of possible additional uses of the third-generation satellites for other programmes whose information requirements are comparable: disaster-relief activation (Office of the United Nations Disaster Relief Co-ordinator (UNDRO)) and World Meteorological Organization (WMO) programmes.

TABLE 1. Schedule and cost of deployment and operation of ISMOS



System cost assessment:

Space segment. Optical satellite $300 million; infra-red satellite $350 million; radar satellite $300 million. Estimated cost range (including R&D) $1,000-1,500 million.

Ground segment. Initial investment $200 million. This includes the analysis centre with its computers, data-retrieval and processing systems, plus the fixed and mobile command and data links and transportation.

Running costs. $125 million per annum. Includes $55 million on trained operations personnel (1,000). $15 million on R&D personnel (100). $25 million on software-development contracts and the balance for equipment maintenance and small-scale R&D in house.

The role and functions of ISMOS

In order that ISMOS may make its greatest contribution to international peace and security, it is important that the information acquired be made available, under agreed rules and procedures, in accordance with the Charter of the United Nations.

In its initial stages the political utilization or application of the data should be restricted to such obvious and necessary special situations as:

Where an individual country requests information or data about itself to be made available to it or be made public.

Where two or more countries agree that information or data about them be made available to them or be made public.

In accordance with the terms of any arms limitation or disarmament agreements.

Pursuant to any cease-fire ordered by the United Nation Security Council.

In the case of any situations, disputes or threats to the peace when ordered by the United Nations Security Council.

The information gathering, processing and use night best be handled in a manner appropriate to each of the above categories.

Among the many missions or functions where satellite monitoring might play an important role, the following come most readily to mind:

Reassurance and confidence-building as an inducement to enter into agreements.
Verification of compliance with international agreements.
Surveillance as a deterrent to violation of agreements.
Conflict anticipation for preventive diplomacy.
Early warning of preparation for possible attack.
Evidence of aggression (border violations, etc.) for adjudication.
Monitoring of cease-fires and of demilitarized zones.
Communication with international observers.

Certain participants questioned the full effectiveness of satellite technology in undertaking these tasks. They maintained, for example, that for strategic arms limitation, satellite observations are useful in those circumstances when the parties do not camouflage their activities, while for many tactical situations interpretation of confusing detail would give satellite imaging limited value. For crisis situations it is by no means clear to what extent a nation which felt threatened or the responsible international bodies could make effective use of information supplied by ISMOS. These views were not shared by most, who nevertheless agreed that ISMOS could not by itself provide the answers to all the problems mentioned. More affirmatively, some participants stressed the need to consider ISMOS within a wider network or arrangements designed to promote regional and global confidence and security, necessitating a variety of means for their implementation.

Constitutional considerations

The original French proposal envisaged that the satellite-monitoring system should be established as a Specialized Agency of the United Nations. Most participants considered that it was a desirable goal that ISMOS should be a part of the United Nations system, but some felt that if it were an internal organ of the United Nations linked to the Security Council that might provide the best chances of enlisting the co-operation of the two superpowers. Its integration into the United Nations would most clearly show it to be at the disposal of the widest possible international community, and at the highest level. Moreover, it could operate immediately within an established legal framework of guidelines governing sensitive decisions. However, other participants noted that the United States and the USSR, which possess the major satellite capabilities, had expressed reservations or doubts about any ISMOS, and therefore suggested that it might prove necessary to consider alternative ways of initiating ISMOS.

Two other possible models for starting ISMOS were considered. In one, the western European countries would take the initiative, in the light of their technical capabilities, but a much wider group of nations would be progressively involved. In the other, a group of countries acceptable as 'neutral' by the potential users would operate ISMOS, buying their technology where necessary, and also involving other (including Third World) countries, in the implementation and decision-making processes.

Some participants wished to know whether, in the absence of the resources of the United States and the USSR, ISMOS would be in a position to accomplish its assigned goals. It was felt that while some of the required technology would be immediately accessible, other aspects would need development effort. This would not be beyond the reach of the consortia of nations considered, provided that enough financial and human resources

were brought to bear. It would be necessary for a steady effort to be deployed over a period of years, and this presupposed the required political will.

Certain participants emphasized the particular political difficulties that would arise if the two superpowers were not members of ISMOS. Even those disposed towards organizing ISMOS in the first instance outside the United Nations hoped that progress made in obtaining the co-operation of the United States and USSR would lead towards eventual United Nations auspices, with full superpower agreement.

Political and legal considerations

It was generally recognized that each state or any group of states had the sovereign right to acquire information necessary for its security by any means permitted by international law.

The question of national sovereignty as affected by the overflight of monitoring satellites was discussed in the context of international law. It was pointed out that the international community, despite opposition expressed from time to time, has more or less accepted the existing situation as far as military and earth resources satellites are concerned. The question would, however, become more pointed if such data were transmitted to third parties.

Dissemination of information was felt to pose special difficulties, largely political and legal in nature. To disseminate raw data would discriminate against those nations not possessing the technical means to process it. Many states would object to the automatic dissemination of economic as well as of military information without the consent of the state or states concerned. Some participants felt that these problems might be more readily solved within the United Nations framework. Others pointed out that the use of previously agreed guidelines for settling disputes about dissemination, together with a case-by-case attention to specific problems was an approach which could be used with success irrespective of the framework of operation.

It was felt that some problems would arise for ISMOS regardless of its institutional framework. These were principally about the sensitivity of data, its safe storage and confidentiality, and its objective interpretation and fair dissemination in accordance with agreed rules. Examples were cited illustrating the importance of verification in the interpretation of satellite data by comparison with information obtained on the ground for co-operating member states. The importance of training image interpreters during the early phases of ISMOS, and obtaining data on a regular basis in order to be able to monitor changes were also stressed in this context.

On the positive side it was noted that as the capabilities of civilian earth resources satellites improved, and a global 'open skies' situation was approached, some of the objections raised against ISMOS would lose their force. Some participants were hopeful that ISMOS would prove to be a sufficiently effective component in a global security system that the two superpowers would feel able to act fully and co-operatively with it. All agreed this to be a highly desirable objective that would be attainable if the implementations of ISMOS came to be accepted as an important part of a cohesive policy directed towards the long-term preservation and promotion of international peace and security.

Conclusions[1]

1. An international satellite monitoring system (ISMOS) is technologically feasible at the present time, given the necessary political will and economic resources for such an undertaking. From a realistic viewpoint, however, substantial technical, political, legal, organizational and financial obstacles would have to be overcome.
2. Such a system under appropriate circumstances could be an important component of a global security system set up for the purposes of verification of certain arms-control agreements, the implementation of decisions of the United Nations Security Council, and in the management of some military crises.
3. The precise role and function of ISMOS would have to be defined in the treaty or statute establishing the system. This instrument would have to define the rights and duties of the parties and the rules and procedures for the collection, storage, interpretation and dissemination of the data.
4. At best, some years would be required before a highly effective satellite monitoring system could be mounted and be made fully operational. To hasten this process, further steps and studies should be undertaken as soon as possible, and in parallel, to promote this proposal both within and outside the United Nations framework. The eventual incorporation of ISMOS into the United Nations system is envisaged.
5. Several optional modalities for the establishment and development of ISMOS should be explored. These should include the extensive use of existing satellites and data collection, analysis and dissemination systems with the ultimate aim of achieving an independent and self-sufficient mechanism which would evolve with experience to meet its objectives and purposes. ■

Note

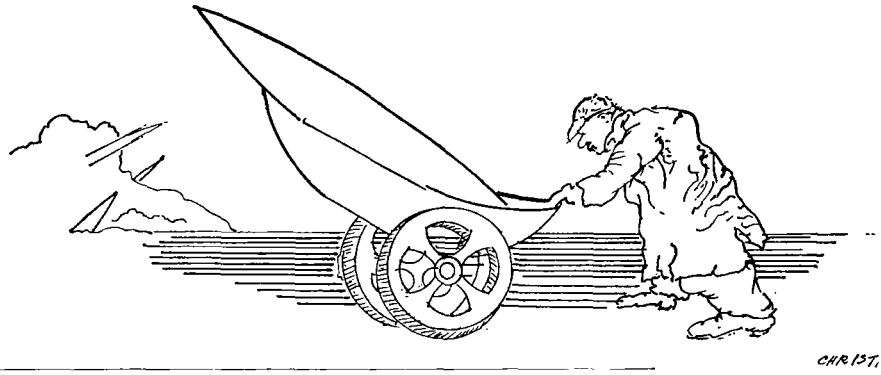
1. These conclusions, discussed in the final session of the symposium, represent a consensus among the discussants. However, it should be stressed—in the spirit of Pugwash—that being listed as a symposium participant does not necessarily imply acceptance of every item in these conclusions as stated.

The success of any process designed to monitor military uses of scientific and technical research is contingent upon a context of dialogue and collaboration between the major powers as well as among the other countries

impact *of science on society*, Vol. 31, No. 1, 1981

Science and armaments: restoring the primacy of politics

Pierre Dabezies and J.-F. Bureau



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His co-author, Jean-François Bureau, is research assistant at CEPODE and assistant lecturer at Paris XI University (Orsay). The authors can be contacted at Centre d'Études Politiques de Défense (CEPODE), 9 rue Melher, 75004 Paris. Tel. 278.33.22.

No change without conflict

Science and research are the one area which has witnessed the most drastic break with the old order since the Second World War. Indeed, never before has science been so closely associated with the production of armaments.

The First World War unquestionably demonstrated how scientific discoveries and technical inventions could lead to changes in the tactical field; the machine-gun and the use of aviation in battle are cases in point. However, the novelty, so to speak, of the Second World War, was to transform radically the relation between the scientific community and governments. The point in question is no longer merely to apply the most recent scientific discoveries to weapons but henceforth to modify the actual conditions of scientific research with a view to its serving first and foremost the nation and the state in particular.

Gone are the days of the research scientist isolated in his laboratory with little means at his disposal. The scientist now works within a team and is given considerable public or private financial assistance. In other words, scientific discovery has become an institution. Although chance played its part well, one is tempted to think that from now on planning and programming are better guarantees of success.

This change, coming about as it did during the last war, affected primarily the relations between science and armaments. It is common knowledge that such a change did not occur without conflict; the dread inspired by the appearance of nuclear weapons on the international scene led a good many scientists—especially American and European[1]—to call into question the possible military uses of science. One can hardly say there has been much ground for dispelling these anxieties over the past three decades.

Technological transfer and armaments

In fact, not only have armaments systematically benefited from scientific progress but research and development orientated specifically to military ends has been significantly increased. No wonder it has been exposed to so much criticism.

In the first place, military research and development constitutes, in the eyes of its detractors, a considerable misallocation of resources that could better be used for civilian purposes. It is estimated, for example, that the overall resources devoted throughout the world to military research and development since 1960[2] amount to 370,000 million dollars and that 25 per cent of the world's scientific manpower is engaged in military-related activities. Similarly, 40 per cent of the global research and development expenditure since the Second World War has been allocated for military purposes.[3]

On the other hand, military research and development expenditure is heavily concentrated in the developed states. Eighty per cent of military research and development is carried out by the United States and the Soviet Union (this ratio would increase to 95 per cent if, to these two states, one were to add the United Kingdom, France and the Federal Republic of Germany).[4] Of the developing countries, only China also has a significant military research-and-development programme.

Thus, the states with the major military research and development programmes are likewise those who assign the largest budget to military

expenditure and who finally are the main arms exporters. A correlation indisputably exists between military power and arms research and development. One could go so far as to say that military research and development is an attribute of power in the order of international relations.

Cost and amortization

The above, in addition to the motive of independence, no doubt explains why certain developing states (such as Brazil, India, the Republic of Korea) henceforth seek—not just to acquire weapons from the exporter states—but rather to profit from the transfer of technology capable of increasing their potential in terms of engineers and technicians in the advanced sectors concerned (electronics, aeronautics). For example, many arms contracts provide for clauses on production under licence in the purchasing countries or transfer of patents.

However one may question the enhanced independence gained by such technology transfers,[5] these are undoubtedly viewed by the developing states as a means of acceding to the most advanced technologies, the mastery of which is a sure way to reinforce the regional power status to which they aspire. By the sheer volume of the resources it mobilizes, military research and development is certainly open to criticism. In fact, it tends to orientate the whole technological development of the industrial societies. No less responsible is its influence on the evolution of military expenditure and consequent behaviour patterns.

Indeed, the systematic application of the most advanced scientific and technical know-how to arms has two main consequences: on the one hand, the unit cost of weapons is highly increased, every system being replaced by a more sophisticated and therefore costlier weapon;[6] and, on the other hand, the system's amortization period is considerably reduced by obsolescence resulting from the production of higher-performing equipment.

These two factors combined have a cumulative effect on the volume of resources allocated to army defence equipment. The drive to increase military expenditure is therefore due far more to the permanent qualitative modernization than to their quantitative increase.

So-called 'soft' technologies

The needs of defence research and development (more than any other imperative), subjected as they are to be interests of power or to the perfection of ever more elaborate weapons, foster the mobilization of considerable resources—so much so, that it is not rare to see some research and development programmes designed for civil applications benefit more widely from funds when put at the service of defence rather than development projects. One even begins to wonder whether certain technologies only have the chance to see the light of day when put at the service of the armaments programme.

The Pentagon (though not alone in this case) has recently provided a further example of this state of affairs by financing, jointly with the Department of Energy, a study aimed to evaluate the possibility of using solar cells as energy generators for the propulsion of intercontinental mobile MX missiles. The solution of the MX propulsion problems apart, Pentagon officials did not disguise the fact that by thereby subsidizing research and development on solar energy, they were banking upon the creation of a

genuine solar-cell industry which no civilian project had yet been able to achieve.[7] Moreover, the most important equipment on solar energy functioning in the world today is the Mount Laguna radar used by the United States Air Force.[8]

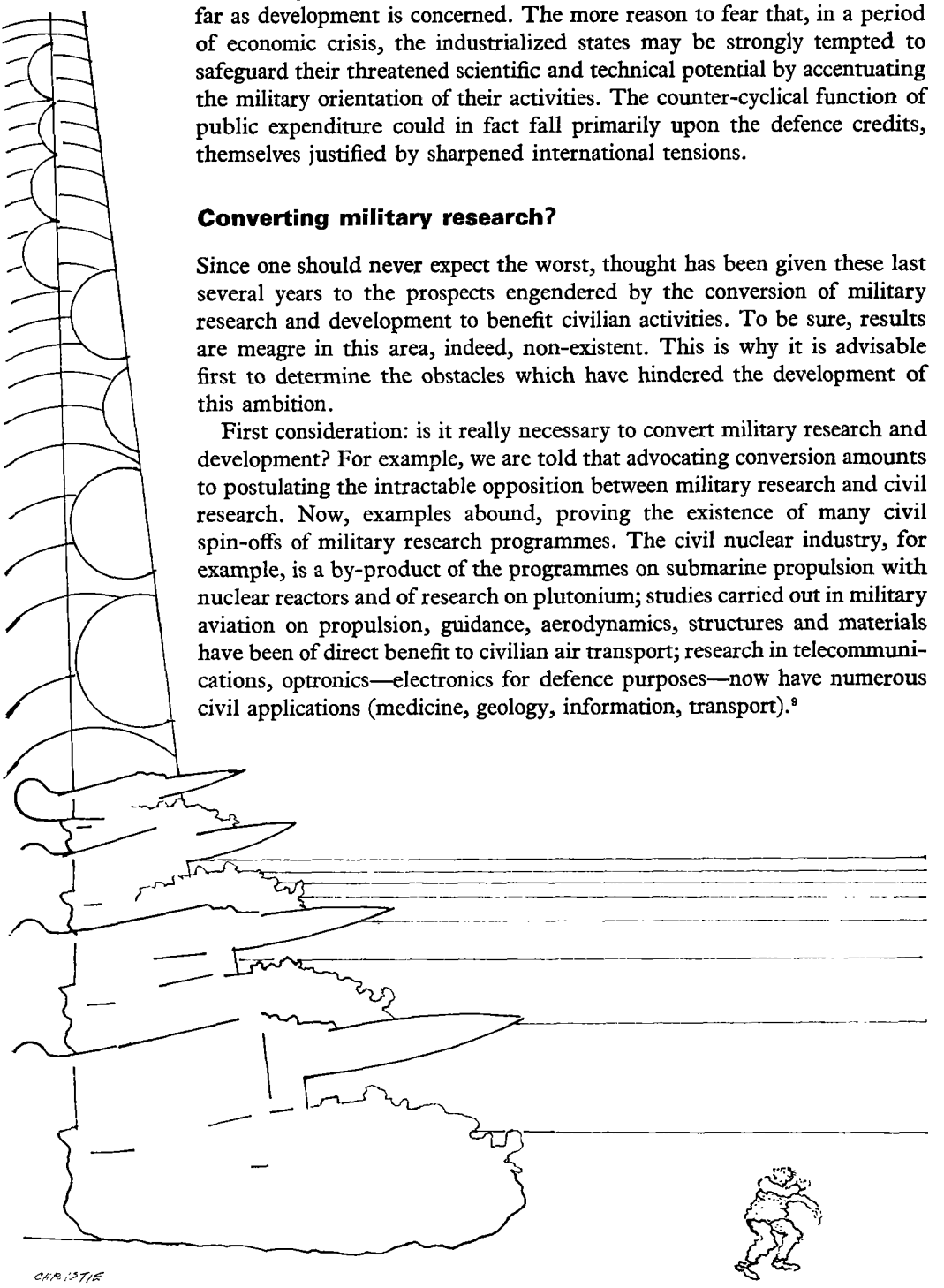
This confirms the fact that certain technologies, however soft, owe their development to their possible use for military objectives.

To many, this situation is evidently dangerous for peace and perverse as far as development is concerned. The more reason to fear that, in a period of economic crisis, the industrialized states may be strongly tempted to safeguard their threatened scientific and technical potential by accentuating the military orientation of their activities. The counter-cyclical function of public expenditure could in fact fall primarily upon the defence credits, themselves justified by sharpened international tensions.

Converting military research?

Since one should never expect the worst, thought has been given these last several years to the prospects engendered by the conversion of military research and development to benefit civilian activities. To be sure, results are meagre in this area, indeed, non-existent. This is why it is advisable first to determine the obstacles which have hindered the development of this ambition.

First consideration: is it really necessary to convert military research and development? For example, we are told that advocating conversion amounts to postulating the intractable opposition between military research and civil research. Now, examples abound, proving the existence of many civil spin-offs of military research programmes. The civil nuclear industry, for example, is a by-product of the programmes on submarine propulsion with nuclear reactors and of research on plutonium; studies carried out in military aviation on propulsion, guidance, aerodynamics, structures and materials have been of direct benefit to civilian air transport; research in telecommunications, optronics—electronics for defence purposes—now have numerous civil applications (medicine, geology, information, transport).[9]



Of course, as the argument goes, it may be plausible to justify an undertaking to which one has initially given priority and allocated resources on the grounds of its chance by-product.[10] Nevertheless, the existence of such civilian applications is perhaps not a purely chance product. In fact, and this certainly explains to a great extent the deadlock that the process of conversion has come to, the very idea of conversion implies the existence of a category of research and development specifically designed for military purposes.

This postulate inherent in every statement of the problem of conversion[11] is itself probably linked to the acknowledgement of the scientific and technical orientation of the arms race. Now, the weapons revolution which we have been witnessing since the mid–1970s proves that whereas there is a definite scientific conditioning of the arms systems, it is not fundamentally different from the conditioning undergone by civilian technologies.

The question of civil repercussions

In fact, the main features of the arms systems deployed over the last ten years are:

Precision (cruise missiles, intercontinental land-based missiles, multiple independently targeted vehicles).

Miniaturization and concentration of power (sub-kilotonne charges, lasers, particle-beam weapons).

Mobility (nuclear-submarine-launched ballistic missiles, cruise missiles, inter-continental land-based missiles).

These principal developments (which, it must be added, tend to erase the difference in nature that formerly existed between conventional and nuclear weapons),[12] are reflected in many civil applications.

Note, for example, the quest for precision which has radically transformed surgery practice into micro-surgery. Likewise, automation is here and now revolutionizing the conditions of industrial production (robots) and is about to do the same in the tertiary (bureautics) sector. Miniaturization and the concentration of power have modified the practice of medicine, of continental-shelf geological research (off-shore), and even of biology. Mobility, too, has already widely transformed the information process.

It is clear therefore that at the stage of applied research, armaments are not treated as a separate entity, but rather as a part of the aggregate whole of the so-called 'peak sectors'. Naturally, the armaments industry does call on certain technologies more than others, especially the whole area of material physics. Nevertheless, it is proving more and more wrong to assert that there is one scientific and technical research category specifically applied to the armaments sector. On the other hand, what is perfectly clear is that there exists an industrial branch whose very function is to equip the arms systems with the results of applied research.

This state of affairs no doubt explains why the civil spin-offs of military research are as numerous as the military uses of civilian research.

The role of institutionalization

In the light of the above, one would be inclined to think that an answer to the problem posed by the military use of scientific and technical research cannot be stated in terms of conversion at the research stage alone. However, there is a definite heuristic value in posing the problem of the conversion of

research; this leads one to question the nature of the control exerted over scientific research, particularly when the latter is at the service of the armaments sector.

Just as it is possible to testify that the weapons' momentum has escaped all social control,[13] so also can one justifiably doubt the possibility of any real command over scientific development, both at the level of fundamental research and at that of applied research.

But if scientific research has, as a whole, since the Second World War —whatever its aims and whatever the framework of the socio-economic system—submitted to the double logic of organization and institutionalization, it is because it then became clear that the condition for scientific progress resided in the continuity of studies and research.

This institutionalization took on various forms. Whereas the United States has established, through co-operation between state, industry and university, a strong complementarity between fundamental and applied research, France has opted for a concentration of scientific manpower within the big public or semi-public organisms, which, in this way, command the various stages of the research process.[14] It seems that in the Soviet Union research, in effect, is co-ordinated principally under the ministries responsible for the defence industry through a division in work between the academies of science dealing with basic research and the design institutes concerned with applied science.[15]

The problems of applied research

Notwithstanding these different forms of organization, it would seem that once the scientific structure is established, and despite efforts at regulation and co-ordination, keen competition sets in between the different constituent parts.

At the level of fundamental research, the rivalry and competition within the scientific community itself contributes to render any kind of control almost entirely ineffectual. The process of institutionalization of scientific research has thus enabled the scientific community to reinforce its autonomy, particularly with regard to the governments even when the bulk of its resources is provided by the state. In fact, when studies are subsidized by state funds, the length of the study cycle (nowadays of the order of ten years) and the corresponding volume of funds attributed, leave little margin for appraisal by the government authorities. While certain principles have been elaborated to determine, *a priori*, the nature of the anticipated results, fundamental research remains an undertaking that does not lend itself well to any form of planning.

Applied research raises other problems but does not offer any better means of control (at least not in the Western states).

There are currently two ways of dealing with this situation.

First, applied research is carried out in laboratories or experimental centres attached directly to defence institutions. In this case, such centres exert strong pressure on the authorities accountable for their specific weapon (land, sea, air) to adopt the technologies they have perfected (by way of orders for equipment). The authorities, for their part, are inclined to adopt, for economy's sake, the technologies elaborated by the research centres which they have been financing for several years.

Added to these instigations surrounding each particular weapon, the

ambition to master highly advanced technologies plays no mean part in fomenting rivalries among the various sectors of an army. Each one is of course anxious, on the strength of its scientific and technological capacities, to widen the scope of its missions and responsibilities. Some arbitration obviously takes place at the highest levels (combined staff and government) but this is due more to a question of dosage and balance than to the concern to limit technological growth of equipment to the strict essential.

Second, applied research is implemented within the framework of corporations independent of the military institution. However, these are put in a particular situation: as a matter of fact, apart from export, which, as far as weapons go, is as much conditional upon economic considerations as upon political criteria, the corporations are in a situation of acute competition, the state being their only market outlet. Such a monopsonistic situation (the opposite of monopoly conditions) is in theory particularly favourable to the purchaser. Above all, it stimulates the firm to perfect, through applied research, the technology of its weapons systems with a view to augmenting its share of the market. The state, for its part, has all to gain in maintaining this situation of competition: in it lies the guarantee of supply of ever more efficient weapons.

In actual fact, both the firms' interests (i.e. making profit from the research effort conducted over a span of several years,[16] and the state's interests (i.e. maintaining a position of rivalry between the producers of weapons) combine to spur on the perpetual modernization of the arms systems. This does not preclude conflicts and divergences occurring between the firms and the state; indeed, very often the firms complain about the vagueness prevailing as to the aims of the programmes commissioned by the state. More often again, the system specifications established at the start by the armed forces alter as the programmes go along.[17]

The adversaries threatened

As remarked upon earlier, it is rather the combination of prevailing interests (economic and politico-military) than the subordination of national objectives to the 'law of profit' that explains the constant pressure for domestic order put on the technological arms' momentum.[18] It is worth noting, however, that the state widely justifies its needs for weapons systems by pointing to exogenous factors—the presumed technological breakthrough of the adversary in certain fields, the present or future imbalance of power benefiting the 'other', the claimed intent of the adversary to evade measures regulating the control of armaments.

This essentially self-justifying role devolves upon the balance of force between the powers and upon the supposed intentions of the adversary; it explains (partly, at any rate) the relative subordination of the strategical doctrines with regard to the level of scientific and technical development of weapons systems.

Nevertheless, defining strategy and tactics on the basis of scientific and technical development seems to occur much more readily within the context of conventional weapons and, in certain circumstances, in that of tactical or theatre nuclear weapons.[19] Conversely, where strategic nuclear weapons are concerned, the issue is much more that of a dialectical relation between strategic doctrine and level of scientific development than the mere deter-

mination of doctrine through science. This is due to the nature of the weapons concerned: their capacity to destroy an entire society compels the political authorities to exercise prudence and judgement in putting them to use. Whoever possesses such weapons knows of course that too great a reliance on one's intentions with regard to the technical capacities in one's possession, could provoke the adversary into a reaction threatening the very existence of the society one is supposed to protect. Political power has therefore concentrated its efforts primarily on controlling the development of strategic nuclear weapons.[20]

On the other hand, it is to be feared that recent interest in the scenarios offered by selective or limited nuclear striking force—as much in the United States as in the Soviet Union—would lead to a relaxed political control over nuclear weapons. This tendency paves the way for increased scientific and technological pressure[21] on the development of such weapons leading to new arms-race spirals. Correlatively, relaxed political control over these systems jeopardizes, to say the least, the outcome of any new negotiations on arms limitation.

Dialogue and co-operation

Institutionalization of scientific research, technological modernization of weapons, these two phenomena are indissolubly linked. This, however, is not due, as one too often hears it said, to a machiavellian trait characteristic of military men, scientists and arms industrialists. Rather, it bears witness to the high priority given to the will for power. In the order of international relations this will for power is more often than not assimilated to the idea of armed security: the 'culture of weapons' is no doubt the widest shared culture in the world.

Last but not least, despite countless phenomena of internationalization and transnationalization, the quest for military power sustains the state in its major role on the international stage. For this reason, any process designed to monitor military uses of scientific and technical research can only be successful within a context of dialogue and co-operation, not only between the major powers but also at the local and regional levels.

It is therefore first and foremost the responsibility of politicians: there is indeed no substitute for the will for peace. ■

Notes

1. As is known, Bertrand Russell was one of the principal instigators of the Pugwash movement, which gathers together scientists who are greatly concerned with the contribution science could make towards peace.
2. R. Sivard, *World Military and Social Expenditures, 1979*, p. 10, Leesburg, Va., 1979.
3. *Les conséquences économiques et sociales de la course aux armements et des dépenses militaires*, New York, United Nations, 1978, No. 67 (Sale No. F. 78.IX.1).
4. R. Forsberg, *Resources Devoted to Military Research and Development*, Stockholm, SIPRI, 1972.
5. Cf. P. Lock and H. Wulf, 'The Economic Consequences of the Transfer of Military Oriented Technology', in M. Kaldor and A. Eide (eds.), *The World Military Order, The Impact of Military Technology on the Third-World*, London, Macmillan, 1979.

6. Cf. M. Leitenberg, 'The Dynamics of Military Technology Today', *International Social Science Journal*, Vol. XXV, No. 3, 1973, p. 336.
7. See *Armed Forces Journal International*, January 1980; *Business Week*, 15 November 1979.
8. *Defence Market Sales—Intelligence on Aerospace*, Vol. 7, No. 46, 12 November 1979.
9. See, for example, the case of France: Y. Bourges, 'La contribution de la défense à la recherche et aux progrès scientifiques et industriels', *Revue de la Défense Nationale*, January 1980, p. 7–22.
10. Leitenberg, op. cit.
11. See *The Sandefjord Report on Disarmament and Development*, Oslo, Ministry of Foreign Affairs, May 1980, particularly pp. 45–62.
12. It should also be noted that cruise missiles, which in themselves display all the features of the new weapons, give a pretty exact idea of the essential characteristics of future systems.
13. M. Thee, 'The Dynamics of the Arms Race, Military R&D and Disarmament', *International Social Science Journal*, Vol. XXX, No. 4, 1978, p. 904.
14. On this point see the *Report of the Research Committee* (edited under the auspices of the Commissariat Général du Plan within the framework of the preparation of the VIIIth Plan), Paris, La Documentation Française, 1980. The report moreover recommends greater decentralization of research, especially in the direction of industry and the university, with a view to developing applied research.
15. See D. Halloway, 'Military R.D. in the Soviet Union', *Bulletin of Peace Proposals*, Vol. 9, No. 1, 1978, p. 534.
16. On an average, expenditure is distributed as follows: prospective research, report 1; advanced development, report 1; tests and experiments, report 3; production, report 10; cf. C. Herzfeld, 'The Military R.D. Process, A View From Industry', *Bulletin of the Atomic Scientists*, December 1978, p. 33.
17. See, for example, Herzfeld, op. cit.
18. Certain analyses, far too mechanical in our opinion, give the idea that the state (and the Pentagon in particular where the United States is concerned) is purely and simply a prisoner of the economic interests of the armaments industry. This in particular is the analysis referred to by certain Soviet observers. See V. Borisov, *The Pentagon and Science*, Moscow, Progress Ed., 1977.
19. Cf. *The Tactical Nuclear Weapons: European Perspectives*, Stockholm, SIPRI, 1978; see in particular Chapters 3 and 5.
20. SALT I Treaty, concluded in May 1972, demonstrated that it was possible for the political authorities to control the development of certain technologies: in this case, anti-ballistic missiles (ABM).
21. Many indications point to a possible calling in question of the ABM Treaty; see *New York Times*, 14 August 1980.

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Letters

impact of science on society, Vol. 31, No. 1, 1981

Towards a methodology for research priorities

From Lucknow comes the following letter, from Vinod K. Gupta, a researcher in the Planning and Information Division, Central Drug Research Institute, Chattar Manzil Palace, Post Box No. 173, Lucknow 226001, India.

I refer to your issue on Research and Social Goals (Vol. 29, No. 3) and your two recent numbers on Managing the Biosphere (Vol. 30, Nos. 3 and 4). These have underlined how science, technology and society are complexly interrelated and how an understanding of their interactions is necessary to control the scientific and technological revolution. Incorporating social values and an understanding of the impact of science on society requires formal and non-formal methods in order to rationalize decision-making in the management of research. Problems of priorities in research, in addition to its conceptualization and methodology, thus become significant.

Re-examination of the idea of priority is necessary. Basic to research are two processes, conceptualizing problems and generating means for their solution. Semantic interactions of the two form an information base in order to structure logical arguments that can be used to develop priorities. The information base includes the interrelations between science, technology and society. Suitable terminology will be required to transform these interactions into specific language. (This domain is abstract, so it will be difficult to formulate explicit objectives, courses of action and their outcomes.) Analysis of the problem should provide a limited framework for creating the information base and formulating priorities.[1]

Structured logical arguments have adequate conceptual character to (a) represent the power of research to influence or control semantic interactions and (b) make it possible to deal with inherently persistent uncertainty and non-comparability of attributes. At a given level of abstractness, a set of such structured arguments can be constituted, supporting 'candidates' for priority. Priority could be redefined, therefore, as the capacity to bring order among the elements of this set or to establish semantic equilibrium among structured arguments.

Just as concepts can be developed to establish order in a set, a logical network designed to integrate research with human needs could be segregated into various levels (depending upon the degree of abstractness). Priorities determined at each level would have an interdependent pattern in the hierarchy of abstractness. Research priorities would then be worked out,

applying the same definition, i.e. an order is established in the pattern of interdependent priorities.

Implementation of such methodology would require new directions in the institutionalization of decision-making in society which, in principle, should at least emphasize the presence of a decision-maker at each of the levels mentioned. This would ensure his or her participation in the process of formulating priorities.

VINOD K. GUPTA

1. For a detailed discussion, see V. Gupta and A. Rahman, 'Criteria for Working Out Priorities—A Conceptual Framework', *J. Sci. Ind. Res.*, Vol. 35, April 1976.

Surplus books wanted in Sri Lanka

We found the following letter in the mail-box. It comes from Dr Buddhadasa P. Kirthisinghe, general secretary of the Society for Asian Affairs, Box 7E, 689 Columbus Avenue, New York, NY 10025, United States of America.

May I appeal to your readers to send all their unwanted books, whether used or new, to a new library in Sri Lanka (formerly Ceylon)?

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BUDDHADASA P. KIRTHISINGHE

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The next issue of **impact of science on society** will examine the 'state of the art' concerning one of the human organism's five principal faculties, its proper functioning and some of its numerous dysfunctions.

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A workshop on Applications of Weather Data to Agriculture and Forest Production will be held the two days preceding or succeeding the three-day conference. Contact Dr Albert Weiss, (1) (308) 632–2711, for details.

Titles and short abstracts (200–300 words), typed in double space, should be sent to Dr Robert L. Edmonds, College of Forest Resources, University of Washington, Seattle, WA 98195, Tel. (206) 543–2757, United States of America.

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Individuals desiring to contribute to this inquiry are asked to contact one of its co-directors: Professor E. C. Jones, Department of Electrical Engineering, Iowa State University, Ames, IA 50011, United States of America, or Professor C. A. Smith, Department of Philosophy, University of Missouri-Rolla, Rolla, MO 65401, United States of America. All information received will be treated in confidence.

MIRCEN NEWS

Mircen News offers news of regional activities dealing with Unesco's programme in applied and environmental microbiology and biotechnology. In these activities, the microbiological resources centres (MIRCENs) established in Australia, Brazil, Egypt, Guatemala, Kenya, Sweden and Thailand interact closely with several non-governmental organizations such as the International Cell Research Organization (ICRO), the International Organization for Biotechnology and Bioengineering (IOBB) and the World Federation of Culture Collections (WFCC); they are concerned with the use and preservation of microbial strains for deployment in environmental management.

Mircen News, published twice yearly, provides valuable information on the use of non-polluting, low cost technologies. Catalogues of regional cultures of microorganisms of economic importance are listed, with addresses of network focal points.

The publication also guides researchers in applied and environmental microbiology from Africa, the Arab States, Asia, South and Central America, and Europe in order to publish in the regional MIRCEN newsletters.

Information pertaining to the research and training activities of the World Data Centre MIRCEN (registration and dissemination of knowledge of culture collections from sixty-five countries) is made available. The organization of short-term training courses, task-force missions, travelling seminars and the obtention of co-operative MIRCEN research grants are described.

Mircen News promotes co-operation among microbiologists in developing and industrialized countries. Individuals, university departments and research institutes desirous of using the MIRCEN network (joint research activities, exchange of staff and sabbatical arrangements, mutual assistance through provision of research materials, and exchange of reprints) will find useful contact points and addresses in *Mircen News*. Readers interested in receiving *Mircen News* should address their requests to: Dr T. Rosswall, Secretary, UNEP/Unesco/ICRO Panel on Microbiology, Department of Microbiology, Swedish University of Agricultural Sciences, S-750 07 Uppsala, Sweden. *Mircen News* is available at no cost.

Training to avoid conflict

Environmental awareness has provoked, both nationally and internationally, new policies and legislation which are aimed at environmental protection. Of equal urgency is the demand for rapid and worldwide development, to alleviate poverty, sickness and illiteracy and to help provide leisure and prosperity. A conflict tends to exist between the demands for technology and resources and the need to prevent pollution and invoke environmental protection. This conflict is particularly reflected in the demands made on education and training programmes

Education and training at the highest levels, producing professional environmentalists, is accomplished with considerable success through university degree programmes. At the technician level, however, there has been little activity. In far too many industrialized countries, the emphasis on universal academic education has left the training aspects regrettably ignored. A tendency has prevailed in which the university graduate has been underemployed as technician—a practice that must not be accepted into the training programmes of countries seeking industrial development.

The technician requires a different kind of education to the university graduate and, most certainly, a different kind of training. The tasks to be accomplished by each require different skills. The unit cost for the production of a technician should be less, for in an educational sense the technician requires a less academically demanding course and a different type of institutional structure. Graduates and technicians develop with different aspirations. Each is trained to perform tasks with efficiency. Yet the manipulative skills of the technician and the academic abilities of the graduate are not necessarily interchangeable.

If development is to be achieved without destruction of the environment, the training of environmental technicians is of paramount importance and there is an urgent need to establish appropriate training programmes. One such programme has been designed at Farnborough College of Technology, United Kingdom. This programme, leading to a Higher Diploma, trains technicians to monitor the effects of pollution related to all forms of development, including urbanization. Technicians acquire specific skills which enable them to provide accurate data which the specialist or professional graduate can then employ to establish suitable environmental protection and controls. The programme is one of the first of its kind. Interdisciplinary in approach, it examines:

Causes of pollution; sources, transport and distribution.

Effects of pollution—chemical, physical and biological—in terms of both occupational hazards to man and the degradation of the natural environment.

Practical methods of sampling and measuring air, soil and water pollution; effective handling and interpretation of the results.

Conceptual framework related to pollution: economic, ethical and managerial aspects.

Many countries have already shown an interest in the programme. The college is prepared to share its experience with institutions in developing countries which are establishing or wish to establish similar programmes. All inquiries should be addressed to the Programme Directors, Higher Diploma in Pollution Measurement, Farnborough College of Technology, Boundary Board, Farnborough, Hampshire, United Kingdom.

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